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VALIDATION OF A PROTOTYPE HANDBOOK OF DESIGN GUIDELINES FOR USER TRANSACTIONS WITH BATTLEFIELD AUTOMATED SYSTEMS

Synectics Corporation

Raymond C. Sidorsky, Contracting Officer's Representative

Submitted by

Franklin L. Moses, Chief
BATTLEFIELD INFORMATION SYSTEMS TECHNICAL AREA

and

Jerrold M. Levine, Director
SYSTEMS RESEARCH LABORATORY

U. S. Army

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This document presents supplementary products of the third phase of a project to develop and validate human factors guidelines for the design of user transactions with battlefield automated systems. During the third phase, the guidelines were applied to two battlefield automated system developmental programs, each at a different stage in the systems development/acquisition process. Section 1 presents the results of a application of the preliminary guidelines to the VETRONICS (Vehicle Electronics) program. Section 2 presents an application to the VIDS-DMS (Vehicle Integrated Defense System - Data Management System).

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The Battlefield Information Systems Technical Area of the Army Research Institute (ARI) is concerned with helping users and operators cope with the ever increasing complexity of the battlefield automated systems by which they acquire, transmit, process, disseminate, and utilize information. Increased system complexity increases demands imposed on the human interacting with the machine. ARI's efforts in this area focus on human performance problems related to interactions with command and control centers, and on issues of system design and development. Research is addressed to such areas as user-oriented systems, software development, information management, staff operations and procedures, decision support, and systems integration and utilization.

An area of special concern in user-oriented systems is the improvement of the user-machine interface. Lacking consistent design principles, current practice results in a fragmented and unsystematic approach to system design, especially where the user/operator-system interaction is concerned. Despite numerous design efforts and the development of extensive system user information over several decades, this information remains widely scattered and relatively undocumented except as it exists within and reflects a particular system. The current effort is dedicated to the development of a comprehensive set of human factors guidelines and evaluation criteria for the design of user/operator transactions with battlefield automated systems. These guidelines and criteria are intended to assist proponents and managers of battlefield automated systems at each phase of system development to select the design features and operating procedures of the human-computer interface which best match the requirements and capabilities of anticipated users/operators.

Research in the area of user-oriented systems is conducted as an in-house effort augmented through contracts with uniquely qualified organizations. The present effort was conducted in collaboration with personnel from Synectics Corporation under contracts MDA903-80-C-0094 and MDA903-82-C-0245. The effort is responsive to requirements of Army Project 2Q263744A793, Human Performance Effectiveness and Simulation, and to special requirements of the US Army Combined Arms Combat Developments Activity (CACDA), Fort Leavenworth, Kansas.

Individuals contributing to this report include

<u>Army Research Institute:</u>

R. Sidorsky

<u>Synectics Corporation</u>:

J. Gates
P. Grimma
R. Parrish
S. Munger
O. Towstopiat

VALIDATION OF A PROTOTYPE HANDBOOK OF DESIGN GUIDELINES FOR USER TRANSACTIONS WITH BATTLEFIELD AUTOMATED SYSTEMS

BRIEF

Requirement:

To develop a methodology that provides a framework and format for a comprehensive set of human factors guidelines for the design of user transactions with battlefield automated systems for use by human factors specialists and system proponents, managers and developers.

Procedure:

To meet the requirements stated above, a three phase research program was initiated. Phase I was devoted to defining human factors requirements for battlefield automated systems and establishing a framework within which guidelines could be organized. In Phase II, the technical data base was further developed through search of the military and civilian literature related to user/operator transactions with automated data processing systems and a prototype handbook of guidelines was developed. In order to evaluate the utility and usability of the initial version of the handbook, it was subjected to a "validation" process. To carryout this validation process, the guidelines were applied against selected functions associated with the Vetronics and the VIDS-DMS developmental programs.

Findings:

Based on the application of the guidelines to the above two test cases, the format and content of the guidelines are conducive to their use at different stages of the system development/acquisition process. At very early stages (e.g., Vetronics) review of the Methods and Recommendations sections in particular provide good indications for general design solutions. As development progresses, the more detailed information specific to design options presented as Advisory Comments become appropriate.

Utilization of Finding:

The metholology, conceptual framework and format of the guidelines developed in the course of this project appear to provide a productive approach to improving the process of "technological transfer" of data from human factors researchers to other members of system design teams of battlefield automated systems. Judicious application of these guidelines will improve the effectiveness of the soldier/machine interface of future systems and will promote the behavioral interoperability of these systems, i.e., increase the degree to which skills and knowledge can be transferred from one system to another.

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SECTION 1.

Soldier/Machine Interface Issues in the Application of the Vetronics Concept

SECTION 2.

Soldier/Machine Issues in the Design of the VIDS-DMS

INTRODUCTION

This document is one of the products of a project to develop a framework and format for a handbook of human factors guidelines for use by Army system developers and designers, system manufacturers and, particularly, human factors specialists serving as members of design teams of battlefield automated systems. The first phase of the project developed a baseline of characteristics, problems and deficiencies in the soldier/machine interface of existing systems. This baseline provided a foundation for the second phase which comprised a literature survey and preparation of a preliminary version of a prototype design guidelines handbook. The object of the third phase was to evaluate the utility and usability of the initial version of the handbook. The present document details the results of an attempt to validate the utility of the guidelines in a real world context.

The objectives of the "validation" process were to (1) demonstrate the applicability of the guideline, (2) obtain system developer reaction to the guidelines and (3) develop recommendations for revision of the guidelines. To carryout the "validation" process, the guidelines were applied against selected functions associated with the VIDS-DMS and the Vetronics developmental programs. Because of the relative stage of development of each progarm, these two applications afforded very different contexts for guidelines usage.

The first application dealt with soldier/machine interface issues associated with the Vetronics program. The Vetronics program underway under the leadership of the US Army Tank and

Automotive Command (TACOM) has as its object the definition of the system architecture required to support the total integration of armored vehicles electrical/electronic, informational and display systems and technology within the context of the AirLand Battle 2000 concept. The second application dealt with the VIDS-DMS (Vehicle Integrated Defence System - Data Management System) program. The purpose of this program is to provide a data management/display system to coordinate the threat warning sensors, threat reaction devices and crew interaction subsystems of tanks and other armored vehicles.

These two application efforts provided the basis for refinement of the format and methodology for developing design guidelines for user interactions with battlefield automated systems. These refinements have been incorporated into the latest version of a prototype handbook published under separate cover as part of this project.

SECTION 1

SOLDIER/MACHINE INTERFACE ISSUES IN THE APPLICATION OF THE VETRONICS CONCEPT

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INTRODUCTION

Background and Purpose

The interim report is a product of Contract Number MDA903-82-C-0254 sponsored by the Army Research Institute for the Behavioral and Social Sciences (ARI). The project is entitled "Validation of Prototype Design Handbook for User/Operator Transactions with Battlefield Automated Systems." One of the early efforts in this project consisted of two steps:

1. Analyze design issues related to the Soldier-Machine Interface (SMI) in the VEhicle ElecTRONICS (Vetronics) concept.

2. Develop recommended resolutions to a subset of these issues by applying appropriate guidelines from the Prototype Design Handbook for Combat and Materiel Developers.[1]

Synectics developed the Prototype Handbook under a previous contract entitled: "Development of Design Guidelines and Criteria for User/Operator Transactions with Battlefield Automated Systems."[2]

The purpose of this report is to describe activities and findings of the effort outlined above. A supplemental report describes a similar process for a second battlefield automated system, the Data Management System of the Vehicle Integrated Defense System (VIDS-DMS). Both reports recapitulate earlier preliminary versions and set forth findings regarding developer feedback on the readability, interpretability, validity, and applicability of the guidelines selected for each system. Volume I of this Final Report describes the technical approach and rationale for demonstrating the Handbook by application to two systems; summarizes salient points related to SMI analyses and developer feedback; and presents recommendations for improving the content of the guidelines contained in the Handbook. The Revised Prototype Handbook is published as Volume II of this Final Report.

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[1]Parrish, R. N., Gates, J. L., Munger, S. J., Grimma, P. R., and Smith, L. T., Development of Design Guidelines and Guidelines and Criteria for User/Operator Transactions with Battlefield Automated Systems. Phase II Final Report: Volume II, Prototype Design Handbook for Combat and Materiel Developers. Fairfax, VA: Synectics Corporation, February 1982.

[2]Contract Number MDA903-80-C-0094.

Organization of the Report

Part 1 provides an overview of the current definitions of "Vetronics" for the benefit of readers who are unfamiliar with the concept. Part 2, Analysis and General Findings describes the techniques used to analyze the program's projected software requirements and discusses global issues in the design of the soldier/machine interface. Part 3, Projected Software Functions, addresses selected functions separately, first presenting a brief functional description as inferred from available Vetronics documentation. Implications are then derived for the soldier/machine interface and finally recommendations to resolve design issues are presented. Part 4 contains a summary of design issues and recommendations.

Overview of the Vetronics Concept

The Army's Vetronics concept is analagous to the aviation community's Avionics concept. That is, Vetronics is the application of electrical and electronic technology and experience to future ground combat vehicles. Currently, Vetronics applications appear to be restricted to on-board systems; however, later integration of data transmitted to the vehicle from external sources presents no insuperable problems.

A Vetronics Action Team (VAT), of which ARI is a member, has responsibility for defining the scope and requirements for Vetronics. The VAT established the following boundaries for its scope:

1. Define Vetronics and identify those systems and subsystems for which growth potential must exist on board combat vehicles.

2. Define the system architecture required to support the total integration of ground vehicle electrical/electronic systems and technology, as foreseen on the Integrated Battlefield.

The effort reported here is concerned primarily with validating the Prototype Handbook cited earlier. However, it also provides preliminary assistance for ARI support to TACOM in defining and resolving SMI issues of Vetronics--the area of ARI's specific concern as a VAT member.

The Integrated Battlefield concept integrates all Arms/Services and coordinates a variety of sensor, intelligence, tactical, and strategic data to improve the ability of the US and its Allies to face and defeat large and sophisticated enemy forces with conventional weapons. Vetronics, which constitutes an evolving technological development product, is a potential bridge for effective employment of armored vehicles within the AirLand Battle concept. AirLand Battle and AirLand Battle 2000 are doctrine and tactics to provide the US a more versatile, lethal, offense-oriented, mobile fighting force than now exists--and one which has improved capacity for small units to function with greater autonomy than current doctrine permits. The AirLand Battle concept incorporates lighter than current vehicles and forces. AirLand Battle extends through the 1990's; AirLand Battle 2000 doctrine is to serve well into the 21st Century. Thus, the AirLand Battle concepts are addressing battlefields and high technology weaponry over the next three and one-half decades.

ANALYSIS AND GENERAL FINDINGS

Overview

The effort reported here parallels, to some extent, the other effort carried out for validation of the Prototype Handbook against the SMI of the Vehicle Integrated Defense System - Data Management System (VIDS-DMS). This effort differs from the earlier one, however, in that a Preliminary Specification[3] for a Feasibility Demonstration Model of the VIDS-DMS was available from which to interpret and project SMI issues. In the case of Vetronics, documentation has not yet progressed to the stage of preliminary specification. Rather, current Vetronics data are restricted to broad conceptualizations of functions/applications. Thus, much of the discussion in the "Projected Software Functions" section below is necessarily speculative. Nonetheless, these speculations appear reasonable in light of information in the sources available for the analysis.

There were two primary sources for the analysis of the Vetronics concept:

1. The Armored Combat Vehicle Technology Exploitation Concept Plan, a briefing prepared and presented by the US Army's Tank-Automotive Command (TACOM) to the Armored Combat Vehicle Science and Technology (S&T) Program Advisory Council, on 11 February 1982. This plan was prepared in response to a request to TACOM from Dr. Marvin Lasser, Director of Army Research, to provide a plan for involvement of ARI in TACOM technical base activities. It was further requested that this plan pursue products and battlefield automation in tank-automotive applications.

2. The Vetronics Action Team (VAT) briefing, prepared for and presented to the Program Advisory Council for the Tank S&T Base Program, by Donald S. Sarna, Chairman, VAT, Tank S&T Program, on 11 February 1982.

Both of the briefings address issues pertaining to the combat vehicle on the integrated battlefield, focusing, of course, to vehicle electronics--Vetronics.

[3] Draft Procurement Specification: Vehicle Integrated Defense System - Data Management System (VIDS-DMS). Warren, MI: US Army Tank-Automotive Command Research and Development Center, July 1982. (R-3760-10279)

Procedure

The above sources provided information by which to identify and then delimit those aspects of the combat vehicle judged to be part of the Vetronics concept, and which have implications for the soldier-machine interface. While there is some variance in terminology and construct between the two information sources, the following list appears to fairly represent the candidate aspects of the Vetronics capability:

1. BIFF (Battlefield Identification Friend or Foe)
2. Combat Simulation Training
3. Communications
4. Diagnostics/Prognostics
5. Drive System Performance
6. Engine Control
7. GPS Enhancement, Target Cueing
8. Gun Stabilization and Fire Control
9. Integrated Defense System
10. Maneuver/Navigate
11. Mass Data Storage
12. Off-board Sensor Fusion
13. On-board Sensor/Countermeasure Management
14. Platform Support/Damage Control Monitor
15. System Status
16. Tactical Situation Display

Familiarity with the capabilities of the VIDS-DMS, through previous analysis of the VIDS-DMS Feasibility Demonstration Model, suggested that some candidate aspects for Vetronics are already included in the VIDS-DMS. Of the above listed candidate Vetronics capabilities, the following appear to fit this category:

1. Communications. New communications capabilities are not expected to be an integral part of Vetronics. Communication status information will be handled as part of System Status.

2. Routine and exception data for Drive System Performance, Engine Control, and Platform Support/Damage Control Monitor will probably be provided through System Status capabilities.

3. On-board Sensor Countermeasure Management and GPS Enhancement, Target Cueing are assumed to be handled by VIDS-DMS. The Integrated Defense System is the VIDS proper.

Mass Data Storage was eliminated from consideration because it appears to involve no SMI issues. The Gun Stabilization and Fire Control Capability was eliminated because Vetronics does not appear to enhance current capabilities or involve soldier-machine interface issues beyond simple status information discussed as part of System Status. Finally, Off-Board Sensor Fusion was eliminated from consideration because, as noted above, Vetronics appears to be restricted to within-the-vehicle capabilities, and because fusion of data from sources external to the vehicle is part of another development concept now identified as the Integrated Intelligent Vetronics ($VINT^2$).

Thus, the following applications appear to be the only ones having viable soldier-machine interface implications which are specific to Vetronics:

1. BIFF
2. Combat Simulation Training
3. Diagnostics/Prognostics
4. Maneuver/Navigate
5. System Status
6. Tactical Situation Display

For each of the above identified candidate applications, the analysis somewhat speculatively delineated user requirements and derived SMI implications. This discussion addresses types of interactions likely to be required and, where possible, tasks likely to be imposed on the crew. Lastly, recommendations were developed to resolve selected issues implied by the analysis, and sections of the Prototype Handbook containing guidance relevant to those issues were suggested.

General Findings

The soldier-machine interface implications of Vetronics are concerned with providing the combat vehicle crew with that information required to perform their tasks. There are three essential components in the design of the Vetronics soldier-machine interface:

1. Determining what information is required under what circumstances.

2. Limiting the information to only that which is required under the given circumstances.

3. Designing the best data capture/presentation parameters, as appropriate to the information and usage characteristics.

Vetronics is the integrator of a large number of elaborate data sets dealing with such diverse types of information as targets, vehicle status, vehicle maneuver capability, meteorological data, sensor data--all of those types of information identified in Tables A-1 through A-9 in the Appendix. At this stage of development of Vetronics, it seems appropriate to provide general findings with respect to two topics:

1. The volume and type of soldier-machine interface.

2. General design implications.

VOLUME AND TYPE OF INTERACTION

In contrast with the VIDS-DMS, Vetronics appears to require a relatively high interaction with the crew. Although much of the data that will be provided through Vetronics will be entered automatically and not require crew intervention, much of that information will be available to the crew only on demand, i.e., only through crew interaction. Exceptions to this are the warnings and status data presented via the Diagnostics/Prognostics capability.

Operation of Vetronics in a combat vehicle which must maneuver across the battlefield presents obstacles to the crew's ability to handle the volume and varied types of interaction required. The battlefield will add noise and confusion; combat will add stress and the need for quick response. Under these conditions the crew will need to access, review, and coordinate data in the most efficient manner. There must be no cause for hesitation in requesting information, or any ambiguity in interpreting it when it is presented.

Vetronics will greatly expand the the crew's knowledge about the vehicle, the battlefield, and the battle. This expansion enhances the crew's and the vehicle's chances for survival. But improved suvivability comes at the price of a larger and more complicated crew workload, not a reduced and simplified one. Vetronics cannot be allowed to negatively impact crew performance, thereby defeating its purpose of enhancement of combat operations. It must be carefully integrated into the current duties of the crew so that all vehicle and battle-related actions are fluid and coordinated.

GENERAL DESIGN IMPLICATIONS

The relatively expansive data sets and enlarged crew-vehicle-Vetronics interface that Vetronics brings to the combat vehicle, impose some severe design constraints on the soldier-machine interface. Tasks should be structured so that missions can be accomplished with a minimum number of steps and at as minimal a difficulty level as possible. Vetronics tasks should be integrated with other crew responsibilities on the most logical and efficient basis possible. Tasks should conform as nearly as possible to those already within the crew's skill profile. The crew must not be required to master and use complex command languages, extensive interactive procedures, or other sophisticated computer skills.

Information to be presented on displays must be selected in accordance with rigid criteria of relevance and need, so that all essential information--but only essential information--reaches the crew. Information elements must reach the crew at the time and in the sequence in which they are needed. Presentation formats must be designed to present that information logically, in the sequence in which it will be used, and in arrangements on the display that facilitate rapid, accurate interpretation and understanding. At the same time, input methods must be kept as simple and consistent as possible, and be designed for rapid easy entry, while keeping opportunities for crew members to commit errors to the absolute minimum.

Vetronics offers a most plausible and fortunate opportunity for design and development of a comprehensive on-board training module with simulated conditions. This training program should be as functionally representative of the actual Vetronics capability as is possible. Utilization of such a training program module could go a long way in overcoming some of the additional workload imposed on the crew through Vetronics. Design implications for Vetronics are also applicable to the design of the training module.

Issues discussed here could and should be much more thoroughly explored so that the soldier-machine interface issues of Vetronics are attended to in a most positive fashion. These SMI issues should be given careful and continuous attention throughout the development of Vetronics, beginning as early in the design process as possible. While the following sections discuss some SMI issues, these analyses have been based on preliminary information. This document can serve therefore, only as a starting point for the more extensive exploration of the soldier-machine interface that is essential to assure the greatest efficiency and effectiveness of Vetronics.

Maneuver/Navigate

INFERRED FUNCTIONAL DESCRIPTION

There are three roles or situations for the combat vehicle to be considered in the Vetronics capability for maneuvering/navigating with respect to engagement between two antagonistic forces. One of these involves the movement of forces, or the positioning of capabilities, in preparation for combat. A second is actual engagement with the enemy or threat. And a third involves avoidance of the enemy or threat when the outcome will be negative, hazardous, or militarily unjustified. Each of these roles depends upon the crew's ability to maneuver/navigate the vehicle. The crew/vehicle capability to maneuver in a non-combat situation is not substantially different than the battle condition, except that it occurs in a non-threatening environment.

The crew/vehicle function of maneuver/navigate is a continuing process and dependent upon the availability and utility of identified information parameters. Consideration of the Vetronics maneuver/navigate capability provides a set of those information items required by the crew to perform a series of tasks, the composite of which forms the function of maneuver/navigate. The maneuver/navigate capability is discussed in terms of information requirements, information sources, and crew tasks.

Information Requirements

The requisite information for crew/vehicle performance of the Vetronics navigate/maneuver function consists of:

1. Terrain/terrain relief
2. Terrain type/condition
3. Own position
4. Objective/destination
5. Battle plan
6. Attitude

7. Environment

8. Engine/drive status

9. Electrical status

10. Bearing

11. Hostile forces

12. Tank capabilities/characteristics

Each of the information items is described below.

Terrain/terrain relief. Terrain/terrain relief information describes the surface features of a geographical area and is generally provided in a topographic manner through maps. In a combat vehicle, this information is a candidate for presentation graphically through the capability of the Tactical Situation Display. The crew uses the information to determine a route to an objective/destination by matching the vehicle's capabilities against the demands imposed on the vehicle by the terrain.

Terrain type/condition. Terrain type/condition information concerns surface features of a geographical area and can be presented graphically on the Tactical Situation Display. The information covers man-made items (e.g., bridges, roads) and includes identification of areas that offer restrictions to an armored vehicle's progress (sand, marsh, forest, mud, etc.). The crew uses this information to determine routes or alternate routes to an objective/destination by matching vehicle capabilities against terrain features.

Own position. Own position information consists of the latitude and longitude or map coordinates of a combat vehicle's present position. The crew uses this information for vehicle maneuvering and scheduling. It is candidate information to be presented by graphic representation on the Tactical Situation Display. To date, a crew cannot expect to have real-time updates of own position once a mission is underway. (NOTE: Such capability is planned via the Position Locating Report System (PLRS). PLRS is intended to aid the maneuver/navigate capability by presenting real-time own position information on demand by the crew.)

Objective/destination. Objective/destination information represents a decision made by an authority to approach or leave an area or force. The objective/

destination can be represented graphically through the Tactical Situation Display. The crew uses this information for route planning.

Battle plan. Battle plan information is used for maneuvering/navigating as it affects the positioning, deployment, or utilization of the combat vehicle as it approaches its objective. The crew maneuvers/navigates the vehicle to satisfy the requirements of the battle plan.

Attitude. Attitude information concerns the combat vehicle's physical orientation at any given time. Useful attitude information consists of roll, pitch, and occasionally, yaw. The information can be presented digitially, graphically, or as an analog. The crew uses this information to determine how close their vehicle is to safety limits and to make decisions as to maneuvering. This information is presented through the System Status capability.

Environment. Environment data describe the natural environment surrounding the combat vehicle's position. Data include rain, smoke, fog, ice, snow, outside temperature, and remaining light. Changes in the environment during the conduct of a mission can adversely affect the combat vehicle's mobility. This information can be presented digitally or as an analog. Crews will use environment data to make decisions affecting battle plans, available routes, and maneuvers.

Engine/drive status. The engine/drive status information describes the status of some of the combat vehicle's motive systems. Included are engine oil temperature, pressure, and level. Also included are engine power or RPM, exhaust gas temperature, remaining fuel/fuel consumption, and transmission oil temperature. In the event that systems are installed that utilize engine bleed air or hydraulic pumps, then pressure information from these systems will be required. This information can be presented digitally, as an analog, or graphically through the System Status capability. Impending failure and trouble indications and accompanying information are presented via the Vetronics Diagnostics/Prognostics capability. The crew uses this information to make decisions regarding available routes, changes in plans, and to make repairs.

Electrical status. Electrical status information is concerned with the operation of the engine-driven alternator/generator or other power source for the combat vehicle's electrically powered devices. In the event of a failure in the engine-driven alternator/generator or primary generating device, the crew will need to make decisions based on the output and life expectancy of the auxiliary power source. Should only the battery remain, the crew will need to know that also. Degraded range or operability may cause the crew to select different routes or make repairs. The System Status capability provides this status information.

Compass bearing. The compass bearing describes, in degrees, the combat vehicle's present heading. The information can be provided digitally, as an analog, or graphically on the Tactical Situation Display. The crew uses this information in determining their present position for navigating and maneuvering. This information may be available via the System Status capability in lieu of or in addition to the Tactical Situation Display.

Hostile forces. Hostile forces information describes the threats to and objectives of the combat vehicle. The data can be provided digitially or graphically on the Tactical Information Display. Information consists of known hostile sensors and weapons locations and of mobile forces' last known positions. This information will be available to the crew while the vehicle is in garrison (pre-attack staging). Once a mission is in progress, data received through the VIDS-DMS will be available to the crew. The information available to the crew consists of warnings as to the detection of hostile scanning by infra-red, laser, or radar frequencies, as well as optical and acoustic detectors. The crew will use this information for immediate defensive or offensive maneuvers as well as alternate route planning.

Vehicle capabilities/characteristics. Information about vehicle capabilities and characteristics is largely acquired by the crew through training and experience. For example, routes are planned by matching the terrain encountered against the vehicle's terrain crossing capabilities. Destinations and routes are planned using knowledge of the vehicle's range and speed over different terrains. Maneuvers are undertaken using the crew's knowledge of the vehicle's turning radius and stability. Information to support the crew while planning maneuvers and navigation can be provided. However, this information is best limited to information already discussed: vehicle speed, remaining fuel, bearing, attitude, engine/drive status, etc. The crew's familiarization of the combat vehicle's capabilities is, to date, expected to be enhanced by but not dependent upon information provided through the Tactical Situation Display.

Information Sources

As indicated in the descriptions of the information requirements, the information comes from a variety of sources, including:

1. Internal storage
2. Crew input/knowledge
3. Derived information
4. Internal sensors/instrumentation
5. VIDS-DMS sensors
6. PLRS, when available

Combat scenarios, projecting future engagements, are one source of data which could be loaded into the vehicle as a basis for the maneuver/navigate capability. These combat scenarios would employ plausible battle plans and strategies and deal with map, terrain, hostile forces, BIFF data, etc., in an attempt to provide as realistic parameters of the combat situation as practicable. The greater the amount of information that can be provided through internal storage, and made available to the crew via the SMI, the lesser is the demand on crew skills and memory.

Crew Tasks

The crew's portion of the maneuver/navigate capability makes use of the available information to perform the following functions:

1. Route availability/planning
2. Maneuvering
3. Scheduling
4. Threat assessment
5. Target selection

During pre-attack staging, the crew loads the most recent/best information available concerning routes, threats, schedules, plans, strategies, etc. Once underway, information will be updated through on-board sensor and status data where possible and, where necessary, through crew observation, communication with other combat vehicle crews, and through the VIDS-DMS.

DERIVED SOLDIER-MACHINE INTERFACE IMPLICATIONS

One conclusion that can be drawn from the preceding discussion is that the maneuver/navigate capability requires substantial support in terms of information both before and during a mission. Also, the requirements on the information are varied. Some information has to be especially accurate, some precise within a range of values, some current to a short time standard, etc. An additional conclusion concerns the differing display requirements for the task support information. Some data will require a tailored display screen and format for maximum effectiveness, while other data can be provided through more traditional or conventional instrumentation. A further implication concerns the duration of the display of information. Requirements vary from a near continuous display, to an "as required" display, to an "exception basis only" display.

The initial evaluation of the information requirements to support maneuver/navigate tasks suggests an information display device or system of considerable capability. The interface area must be large enough to display terrain data over a geographical area suitable in size for combat purposes, and offer resolution and contrast in detail to a level usable by the crew in decision making. Additionally, the interface must provide status/instrument/sensor data, probably through the display, either continuously, on demand, or by exception. The possibility of supplying real-time position locating information through PLRS may become a reality for the Combat Vehicle. This information will be provided to the crew through the SMI and, ideally, graphically through the Tactical Situation Display. While a current SMI does not need to attend to PLRS data, the SMI should be prepared by design for that eventuality.

The crew will also need to instruct the Vetronics system, through the SMI, to display "on demand" data. This data may be engine instrumentation not ordinarily displayed, an expanded scale of terrain data, updated information from the VIDS-DMS, or mission information from additional sources. The crew will therefore need capability to input instructions to Vetronics through the SMI. Given the conditions inside a combat vehicle engaged in action, the input mechanisms and instructions must be simple in demand and limited in number.

RECOMMENDATIONS

1. Sections of the Prototype Handbook relating to display/ interface issues of the maneuver/navigate task are:

   1.1 Alphanumeric Control Methods

   1.2 Graphics Control Methods

   2.1 Alphanumeric Displays

   2.2 Graphics Displays

   2.3 Selective Highlighting

   3.2 Unburdening of Input

   4.2 Composition Aids for Graphics Displays

   5.1 Query Method

   6.1 Symbols and Symbol Sets

   7.1 Error Feedback

   7.2 Error Correction and Recovery

2. Allow sufficient range in the display of terrain data so that both the objective and crew's present position are simultaneously displayed.

3. Provide sufficient terrain relief and artifact features in the topographic display to allow the crew to make maneuver/ navigate decisions.

4. Display compass heading information digitally and continuously.

5. Display updated status information (threat, open or closed bridges, open or closed roads, etc.) through the terrain display as blinking graphics characters. Require the crew to acknowledge these updates through push-push switches.

6. Provide terrain/terrain relief data on the topographic display with enhancements to depict such features as routes negotiable by combat vehicles; bridges; fordable, non-fordable streams; and "slow footing" surfaces.

System Status

INFERRED FUNCTIONAL DESCRIPTION

This capability will check all on-board systems and advise the crew of their status. Some of these indicators will interact with the Diagnostic/Prognostic capabilities for the vehicle's operation. The System Status capability differs from the Diagnostic/Prognostic capability in that (1) it is accessed voluntarily by the crew rather than presented automatically, as is the case with the Diagnostic/Prognostic capability and (2) it reacts across all status dimensions, providing current information regarding normal as well as critical status information. It also interacts with the Tactical Situation Display capability in that it reports on the status of some of the data capture capabilities that report through the Tactical Situation Display.

Typical types of information which the System Status capability will provide include:

1. Drive system status

   a. Fuel status--fuel remaining, current fuel mixture

   b. Oil status--pressure, temperature, oil remaining

   c. Engine temperature, coolant status

   d. Vehicle interior heating/cooling status--current temperature, operability, coolant remaining

   e. Vehicle speed--km/hr, acceleration, engine RPMs, drive mode operability, current drive mode

   f. Current navigational direction

   g. Current steering angle

   h. Vehicle maneuverability status/restrictions

2. Traction system status

   a. Current attitude--roll, pitch, yaw

   b. Current vibration level

3. Platform support/damage control monitor

   a. Terrain crossing status/limitations

   b. Damage status--location, extent, functional limitation

4. Electrical and electronic system status

   a. Engine control system status--charge/discharge status

   b. Back-up electrical system status/availability

   c. Electrical power distribution system status

   d. Vehicular instrumentation system status

   e. Fire control system status

   f. Stabilization system status

   g. Tactical Situation Display status

5. Communications systems status

   a. Operability status

   b. Current utilization--frequencies, assignments

   c. Alternative available channels

   d. Hi/lo power indications

   e. COMSEC status

6. Sensor systems status

   a. NBC threat system status

   b. Fire threat system status

   c. Laser threat system status

   d. Optical threat system status

   e. Enemy helicopter (acoustic) threat system status

   f. Thermal sight system status

7. Countermeasure systems status--operability, orientation/aim

   a. NBC protection system status

   b. Fire suppression system status

   c. Optical jammer status

   d. Semi-automatic counterfire status

   e. Laser shutter status

   f. Smoke/decoy system status

8. Weapons systems status--for each on-board weapon

   a. Operability

   b. Orientation/aim

   c. Temperature

   d. Ammo loaded

   e. Performance capability--range, accuracy, elevation limits, kill probability or target dependencies, train rate

9. Ammunition status

   a. Types

   b. Amounts available

   c. Usage rates

Some of the status indicators listed above will be routinely available to at least some of the crew via standard displays, e.g., the vehicle's speed will be available to the vehicle driver via the speedometer; the radio operator will have firsthand knowledge of frequency assignments. But it also will be necessary for the tank commander at times to access a variety of different status informations on which to make decisions and by which to forward information to the unit commander.

DERIVED SOLDIER-MACHINE INTERFACE IMPLICATIONS

Vetronics must provide the essential on-board visual displays and other crew interface devices necessary for the vehicle crew and the crew commander to perform effectively. These devices must provide the essential information when needed, present no more information than needed or requested, and produce the information on a timely and accurate basis.

The great number of potential status indications listed above (and there are undoubtedly many more), and the environment in which the information will be requested and used, present some serious implications for the design of the devices. Continual display of all status indicator dimensions is out of the question for two reasons: space limitations within the vehicle and sensory over-saturation of the crew. Thus, it is imperative that individual crew members have the capability to access specific pieces of system status data on command. Further, likely all, or nearly all, status information should be accessible to the vehicle commander, likewise on command and independently. Space limitations within the vehicle have implications for multi-function controls and displays, i.e., utilization of mode controls to expand individual controls and displays to multi-function capability.

Use considerations will probably indicate certain configurations of status data. Analyses should be made to determine what these combinations ought to be. Configurations of status data could greatly reduce the crew's burden of learning and using independent request sequences for separate pieces of data. Standardization of request and display features is also in order. For example, countermeasure systems status data could standardly provide operability and orientation/aid information for each countermeasure type. Standardized formatting of requests (inputs) and of information presentation (outputs) are appropriate here.

The choppy nature of the battlefield terrain poses severe problems for the design of controls and displays. Keyboards, small function keys, and touch panels are poor candidates for accurate insertion of commands in a moving vehicle on a volatile battlefield. Such uneven hand manipulation conditions usually indicate the need for utilization of speech commands. However, the noise of the battlefield will impact the efficacy of use of voice as a control medium. Consideration should be given to employment of dual command/ request capabilities--i.e., utilization of both manual and voice inputs.

RECOMMENDATIONS

1. Standardize the System Status command/display features to the extent possible.

2. Determine and implement status data configurations to reduce crew burden in accessing status data.

3. Employ multi-function controls and displays to accommodate to within the vehicle space limitations.

4. Provide dual command/request media to overcome the difficulties of the battlefield environment.

5. Sections of the <u>Prototype Handbook</u> relating to the SMI of the System Status capability are:

   1.1 Alphanumeric Control Methods

   1.2 Graphics Control Methods

   1.3 HELPs

   2.1 Alphanumeric Displays

   2.2 Graphics Displays

   3.2 Unburdening of Input

   4.1 Composition Aids for Alphanumeric Messages

   4.2 Composition Aids for Graphics Displays

   5.1 Query Method

   5.2 Query Structure

   6.1 Symbols and Symbol Sets

   6.2 Standard Terms

   6.3 Abbreviations and Codes

   7.1 Error Feedback

   7.2 Error Correction and Recovery

Diagnostics/Prognostics

INFERRED FUNCTIONAL DESCRIPTION

This capability will provide diagnostic and prognostic information to the crew when vehicle failure or critically reduced vehicle performance capacity is indicated. Typical types of information might include:

1. For a low fuel status indication:
   a. Amount of fuel remaining.
   b. Achieved rate of consumption under known conditions.
   c. Average rate of consumption.
   d. Navigable distance remaining under different speed conditions.
   e. Turn-around point/distance to reach refueling station safely.
   f. Information regarding vehicle failure condition causing undue loss of fuel.
2. For a low oil pressure status indication:
   a. Actual pressure reading.
   b. Reason for oil pressure failure.
   c. Projected time/distance to "dead" or critically damaged status.
   d. Oil quantity remaining.
   e. Oil temperature.
3. For an overheated engine indication:
   a. Actual temperature reading.
   b. Reason for engine overheat.
   c. Projected time/distance to "dead" or critically damaged status.
   d. Projected cool-down time to bring engine to within-tolerance temperature.

4. For a malfunction indication in the vehicle's heating system:

   a. Nature of the malfunction.

   b. Highest/lowest internal vehicle (crew area) temperature expected after what duration of time.

5. For a malfunction indication in the vehicle's cooling system:

   a. Nature of the malfunction.

   b. Highest/lowest internal vehicle (crew area) temperature expected after what duration of time.

Routine status of any of the above systems will likely be indicated to the crew through standard automotive displays such as meters, gauges, and indicator lights. Such displays have the capacity to inform the crew of normal operating status and even to indicate trouble symptoms. However, the nature of the environment in which the crew and vehicle function is such that under some conditions inadequate attention might be paid to routine display of malfunction indicators--in the middle of heavy battle, for example. The Diagnostics/Prognostics function differs from routine status readouts in the following ways:

1. It calls out a "trouble" condition rather than routine status.

2. It identifies the nature of the "trouble," thereby allowing the crew to make a decision as to how to handle the problem--e.g., repair, return, ask for help.

3. It provides additional information to assist the crew in making the above decision--e.g., for a low fuel status indication, the turn-around point/distance to reach refueling station safely; for a low oil pressure status indication, the projected time/distance to "dead" or critically damaged status.

DERIVED SOLDIER-MACHINE INTERFACE IMPLICATIONS

The Diagnostics/Prognostics capability interfaces directly to the crew via automatic messages. Further, messages of diagnostic/prognostic information should be such that they cannot be overlooked by the crew and, under some conditions, cannot be ignored; but, conversely, under other conditions, a manual override should be possible. These display-response conditions are implicit to the level and/or stage of battle or maneuver. For example, the crew is going to be much more protective of the vehicle during practice maneuvers than during battle--probably opting to return to "garrison" for even the slightest trouble indication. On the other hand, if the battle is all but won, the crew would probably opt to continue even if the vehicle would be out of commission immediately after the last target were taken. These same conditions apply to the vehicle's internal heating and cooling systems, with the crew tolerating temperature extremes for whatever required periods of time more readily under battle conditions than under practice maneuver conditions.

Ways in which the crew could be notified of vehicle problems or malfunctions--when there is an implication that the problem or malfunction is likely to disable the crew or the vehicle--include an aural message; a textual message via a display screen identifying the system at fault and the nature and severity of the trouble; a series of blinking lights which identifies the system at fault; or a larger set of blinking lights which also identifies the nature of the problem. Some combination of aural, blinking lights, and textual information to the crew is probably required--aural notification to gain the attention of the crew--although even that poses some problems under battle condition--and visual display to provide specific diagnostic and prognostic information.

The crew should be required to acknowledge the message through a simple mechanism such as a push-button. But, the crew should also have the option of indicating to the Diagnostic/Prognostic capability that no immediate attention will be given to the problem.

RECOMMENDATIONS

The following recommendations assume more than simple provision of diagnostic/prognostic information via the Vetronics Diagnostics/Prognostics capability.

1. The crew should be notified immediately when conditions indicate a potential vehicle failure or a critically reduced performance capacity. This message should be in three parts:

a. An aural indication, e.g., bell, siren, which precludes the crew's overlooking the message.

b. Notification of the "threatened" vehicle system.

c. Substantive information about the nature of the trouble from which the crew is able to perform decision-making as to corrective options.

Notification should remain on the display device(s) until acknowledged by the crew.

2. Sections of the <u>Prototype Handbook</u> relating to display issues in the Diagnostics/Prognostics capabilities of Vetronics are:

   2.1 Alphanumeric Displays

   2.2 Graphics Displays

   2.3 Selective Highlighting

   4.1 Composition Aids for Alphanumeric Messages

   6.1 Symbols and Symbol Sets

   6.2 Standard Terms

   6.3 Abbreviations and Codes

3. With respect to the crew's ability to override the diagnostic/prognostic notification, the crew needs control methods capabilities. Relevant guidelines for control methods and guidelines appropriate to a manual override are presented in the following sections of the <u>Prototype Handbook</u>:

   1.1 Alphanumeric Control Methods

   1.2 Graphics Control Methods

   3.1 Information on Legal Entries

   3.3 Interrupts and Work Recovery

   4.1 Composition Aids for Alphanumeric Messages

   6.1 Symbols and Symbol Sets

   6.2 Standard Terms

   6.3 Abbreviations and Codes

Battlefield Identification Friend or Foe

INFERRED FUNCTIONAL DESCRIPTION

The Battlefield Identification Friend or Foe (BIFF) system receives and interprets electronic signals defining another combat vehicle's tactical identification as a friend or foe. A future technology is intended to add the capability of identifying neutrals. The BIFF system consists of the following capabilities:

1. Automatic interrogation and interpretation of electronic tactical identification signals received from other combat vehicles.

2. Computer output of identification status (i.e., symbols indicating friend, foe, or neutral combat vehicle).

3. Crew interrogation capability, for verifying computer-determined identification status. The crew interrogation capability consists of:

    a. System capability that allows crew members to electronically "question" other combat vehicles as to whether they are friend or foe.

    b. System capability that allows crew members to verbally request another combat vehicle to further describe itself, thereby providing means for more in-depth questioning and verification.

    c. A developing technology suitable for supporting the BIFF application concerns the detection of vehicle electromagnetic emanations. The signature from these radiations can be detected and electronically compared to stored signatures of hostile vehicles. BIFF information can be gained as a result.

The BIFF system will have two operational modes--automatic and intermittent manual. The electronic interpretation and display of vehicle identification status will be automatic. However, the crew's verbal interrogation capability will be primarily manual with periodic automatic functions.

DERIVED SOLDIER-MACHINE INTERFACE IMPLICATIONS

The BIFF system provides the crew with information classifying combat vehicles as either friendly or unfriendly. On the battlefield, an unfriendly vehicle is likely to be a hostile force and a threat to the combat vehicle.

Integrating the BIFF capability into Vetronics will allow for the presentation of this status information through the Tactical Situation Display. Of critical significance is the display of a BIFF system-defined foe as a warning. This warning should be provided to the crew immediately after it has been determined.

It is assumed that the BIFF system is able to determine that the vehicle is being interrogated by a signal that is not within the specification for friendly forces. The possibility exists that the combat vehicle can be interrogated by a hostile vehicle and the crew should immediately be made aware of this. Armed with this knowledge, the crew can follow procedures established for this situation.

Additionally, the crew may wish to know when the BIFF system is performing its automatic function of responding to friendly interrogation at an unusually high occurrence. An unusually high number or rate of acknowledgements may indicate that the receiving unit in the transmitting vehicle is malfunctioning or not receiving a signal. Radio or other inter-vehicle communication may be advised.

The Tactical Situation Display, as it supports the BIFF capability, provides the crew with real-time notification of probable and possible threat situations. Crew decisions will then be limited to selecting from a limited number of procedural alternatives.

RECOMMENDATIONS

1. Sections of the Prototype Handbook relating to guidelines useful to the incorporation of BIFF capabilities to meet crew requirements are:

   1.1 Alphanumeric Control Methods

   1.2 Graphics Control Methods

   2.1 Alphanumeric Displays

   2.2 Graphics Displays

   2.3 Selective Highlighting

   3.2 Unburdening of Input

   6.1 Symbols and Symbol Sets

   6.3 Abbreviations and Codes

The following guidelines were derived from the Prototype Handbook and tailored to the BIFF application.

2. Display those BIFF-defined foes whose position is known as flashing graphics on the Tactical Situation Display. Use the color red if available, and augment the warning aurally.

3. Indicate aurally and alphanumerically the receipt of unidentifiable interrogation signals.

4. Advise the crew of continuous and repeated BIFF acknowledgements of friendly interrogations.

5. Provide a convenient means for the crew to manually initiate a BIFF interrogation. Provide this capability from two crew stations.

6. Where space permits, provide alphanumeric status displays of uninterrogated vehicles appearing on the Tactical Situation Display. Use "UNKNOWN" status label followed by an aural warning if interrogation is not completed within a specified time period.

Tactical Situation Display

INFERRED FUNCTIONAL DESCRIPTION

Today's combat vehicle employs sophisticated electronics to support and enhance both offensive and defensive roles. The inclusion of the VIDS-DMS, with its peripheral detectors and sensors, provides the combat vehicle crew with early warning of hostile presences. The early warning also furnishes the crew with sufficient information to determine if they should initiate defensive or offensive maneuvers. Electronics supporting fire control systems also provide the crew with the increased speed and accuracy required for increased probability of one shot/first shot kills. PLRS, when available, will provide the crew with on demand, real-time update of the combat vehicle's present position. Additionally, information from instrumentation, internal sensors, and system monitoring devices provides the crew with real-time status indication of the combat vehicle's internal devices.

Internal data storage can hold detailed information identifying terrain features, positions of hostile sensors and weapons, and latest information on the conditions of bridges, roads, and traversable surfaces. Internal storage also holds details of the battle plan, objectives, targets, contingency plans, alternative routes, and rules of engagement. This information is available to the crew on an on demand basis anytime during the conduct of a mission.

At present, the crew must integrate this substantial amount of data, make decisions, and perform some kind of manual response. The substantial amount of data is not, of itself, detrimental to crew performance; data serves a genuine crew function of decision making. Problems arise when the crew must serve as a data integrator, make critical decisions quickly, and perform manual functions. All too frequently, the addition of a new capability to a combat vehicle results in an additional data integration-decision making-task performance cycle for the crew. Increasing the number of automatic assists to the crew aids task performance simply by eliminating those tasks replaced by automatic assists. However, automatic assists are impractical for many combat vehicle tasks, and the crew still has the function of data integration.

Vetronics will offer assistance in relieving this type of workload by integrating the data produced by the combat vehicle's internal systems and providing the data in a usable format through the Tactical Situation Display. The Tactical Situation Display will perform the function of displaying data required by the crew to perform tasks. The Tactical Situation Display is a flat display capable of both digital and graphic representation. In a sense, the Tactical Situation Display is the key output device of Vetronics and a principal component of the soldier-machine interface.

DERIVED SOLDIER-MACHINE INTERFACE IMPLICATIONS

Whereas the VIDS-DMS functions in an essentially transparent manner to the crew, Vetronics should come close to being its opposite. Vetronics, through the SMI, can furnish real-time integrated information to the crew on a continuous, as required, or by exception basis. Importantly, the information provided to the crew should be limited to particulars required to perform the tasks, and presented in a format most useful for the decision making or problem solving required by the task. For example, terrain data, topographical features (both man-made and natural), and hostile forces positions, are best represented graphically. This information and format is best suited for supporting combat roles, and the task of Maneuver/Navigate. Data regarding range, elevations, position identification, compass bearing, etc., are best presented digitally. Information of this nature and format is also applicable to the Maneuver/Navigate task. Alphanumeric data formats best communicate Prognostics/Diagnostics information to the crew. Status information such as vehicle speed, fluid(s), temperature, pressure, or level have historically been presented as analogs; existing vehicle instrumentation may continue this trend. Display of routine status data is probably not a function of the Tactical Situation Display. Should the status monitoring sensors determine that a failure is imminent, then status information serves the purpose of a warning. This information may be displayed on the Tactical Situation Display in alphanumeric format.

Data display and/or data storage limitations will restrict the amount of on demand data available to the crew. Decisions of what data to display should be based on priority analyes. Many on demand data items can be assigned to the same area of the Tactical Situation Display to alleviate the data display overload problem. System-generated exception messages can be displayed alphanumerically in a specially reserved space to inform the crew of impending failure.

The Vetronics SMI can provide required information in optimum format (digitally, graphically, or analog) and do so in a continuous, on demand, or by exception manner. Data access by the crew, especially under high stress and physically buffetting conditions, will require special attention in the Vetronics SMI design. Fixed function keys, physically oversized and well spaced for "canned" queries, and function selector knobs limited to no more than two functions will assist the crew in making rapid transactions. The installation of a standard data entry keyboard for use when combat missions are underway should not be considered. The characters and symbols presented on the Tactical Situation Display should be appropriately sized to provide legibility under conditions of vehicle vibration, roll, and pitch. Vetronics' SMI implications, therefore, call for design of a Tactical Situation Display that exhibits such human engineering concepts as viewability, legibility, and operability, as well as incorporation of data management concepts such as rapid access, data formats appropriate to data type, and data integration.

RECOMMENDATIONS

Recommendations 1 through 13 below were derived from the Prototype Handbook and tailored to support the interface design of the Tactical Situation Display.

1. Provide the crew with a display of a geographical area large enough to contain any known hostile weapon position whose range threatens the crew's present position. "Weapons" is not intended to include items such as a foot soldier with a shoulder mounted rocket launcher, or a helicopter presently parked 50 miles away from the crew's position.

2. Provide the crew with a display of a geographical area with a crew-selectable expanded scale. The detail of the expanded scale shall be sufficient to reveal major topographical features and hostile forces threat data.

3. In the event hostile threats are detected at a range beyond the geographical area accounted for by the terrain display's normal scale, provide the capability for automatic switch to expanded scale, if the increased range will reveal the threat.

4. Reserve a section of the Tactical Situation Display for the display of exception messages to the crew. Provide these messages alphanumerically.

5. If real-time information updates include new threat data (e.g., VIDS-DMS data), provide that information with an alerting mechanism, such as blinking lights, inverse video, color code, or audio alert. Require a crew acknowledge through a push-push switch to extinguish the alerting mechanism.

6. If system status information is to be presented on the Tactical Situation Display, require a crew member to initiate a query for it. Exception: If the system senses an impending failure, a notification should be provided automatically.

7. Specify Prognostic/Diagnostic messages to include alphanumeric identifications of the malfunctioning component.

8. Allow sufficient range in the display of terrain data so that both the objective's and crew's current positions are simultaneously displayed.

9. Provide sufficient terrain relief and artifact features in the topographic display to allow the crew to make maneuver/navigate decisions.

10. Display updated status information (threat, open or closed bridges, open or closed roads, etc.) through the terrain display as blinking graphics characters. Require the crew to acknowledge their presence through push-push switches.

11. Provide terrain/terrain relief data on the topographic display with enhancements to include routes negotiable by combat vehicles; bridges; fordable, non-fordable streams; and "slow footing" surfaces.

12. Consider the Tactical Situation Display's characteristics of resolution, size, brightness, contrast, and color capability as a contributing factor in specifying the size of graphics and digital characters.

13. Provide the on demand capability to display the stores inventory through the Tactical Situation Display or a display in close proximity.

14. Sections of the <u>Prototype Handbook</u> relating to display issues which will be helpful in the design of the Vetronics Tactical Situation Display include:

    1.1 Alphanumeric Control Methods

    1.2 Graphics Control Methods

2.1 Alphanumeric Displays

2.2 Graphics Displays

2.3 Selective Highlighting

3.2 Unburdening of Input

5.1 Query Methods

6.1 Symbols and Symbol Sets

6.3 Abbreviations and Codes

7.1 Error Detection/Feedback

7.2 Error Correction and Recovery

EXAMPLE OF HANDBOOK USAGE

As an example, the Prototype Handbook in Section 2, "Display Techniques," presents guidelines on techniques to present information to the crew. Example applications are presented that are relevant to the requirements of the Tactical Situation Display. Three such examples are reproduced from the Prototype Handbook's Section 2.2.2, "Applications for Graphics Displays," items c, d, and e. Note that the applications are weighted toward creating graphics displays rather than their use as an output device. This does not diminish their merit for guidance in developing a Tactical Situation Display, as the information displayed is substantially the same. The three applications are as follows:

"c. Display of topographic features in a representational framework.

EXAMPLE: In a system which provides data processing support to a tactical command and control, a graphics capability is provided. Maps, which are displayed on a plasma screen, can be enhanced by entry/deletion/movement of special symbols and creation of additional symbols--all through use of a series of fixed function keys. The generated symbols (whether standard doctrinal symbols or newly created symbols) can be superimposed on a displayed map to demonstrate, for example, current, future, or historical status of a given geopolitical area. Or, successive overlays can be prepared to show a variety of topographic features, e.g., terrain features, cultural features, rainfall.

"d. Creation of "free-form" drawings and sketches.

EXAMPLE: An artillery system projects battle strategies on the basis of, for example, terrain and cultural characteristics fire power, personnel, and interim battle outcome parameters. The tank commander, working on a map grid of the battle area, creates various map overlays to aid in the planning of battle strategies. Strategies can reflect, for example, destroyed/not destroyed terrain and cultural features; personnel levels available as a result of battle; gun availability and ammo levels; terrain conditions for tank movement. This system does not have the capability to deal with real-time events on an automatic basis. However, the capacity to deal with time-bound events (e.g., rate of advance, time to complete a maneuver) permits the tank commander to project time into the battle strategy.

"e. Display of imagery.

EXAMPLE: Certain types of "field information" are required to be maintained on a continuing basis at headquarters. These data are measured and transmitted automatically as telemetered data. At the receiving station at headquarters, the pulses are converted to automatic graphics output, sometimes in the form of line drawings, sometimes in the form of bar charts, sometimes in the form of color graphics."

Table 1, which is reproduced from Table 2-1 of the Prototype Handbook, illustrates applications and display techniques. The application of the Tactical Situation Display most closely resembles a "Pictorial/Symbolic Presentation." The display technique most suitable and recommended by Table 1 for this application is the graphic type.

Table 1

Display Techniques by Application

	APPLICATION					
DISPLAY TECHNIQUE	Fixed or Free Text Data	Statistical Report	Trend Data	Pictorial Symbolic Presentation	HELPs	Error Message
Alphanumeric	1	1	3	3	1	1
Graphic	3	2	1	1	2	3

KEY:

1 - APPROPRIATE

2 - ACCEPTABLE

3 - INAPPROPRIATE

To further continue the example, methods for implementing graphics displays are also discussed in the Prototype Handbook. A summary of this discussion is presented in Table 2 which is reproduced from Table 2.2-1 of the Handbook.

Table 2

Method of Graphics Display by Application

KEY:

1 - RECOMMENDED

2 - ACCEPTABLE

3 - WORKABLE BUT SUBOPTIMAL

4 - NOT RECOMMENDED OR NOT APPLICABLE

		APPLICATION				
		DISPLAY OF RELATIVE QUANTITIES OR MEASURES	REPRESENTATIONAL PRESENTATION OF RELATIONSHIPS	DISPLAY OF TOPOGRAPHIC FEATURES	CREATION OF "FREE FORM" DRAWINGS OR SKETCHES	DISPLAY OF IMAGERY
METHOD	BAR GRAPH, BAR CHART, HISTOGRAM	1*	2	4	3	1
	FREQUENCY POLYGON, TREND ANALYSIS	1	1	4	3	1
	PIE CHART	1	2	1	3	2
	FLOW CHART, ORGANIZATION CHART	4	1*	4	2	4
	MAP, MAP OVERLAY, CHART	2	1	1*	1	1*
	LINE DRAWING	1	2	1	1*	2

*Recommended as 1st choice for standardization purposes.

The most closely matching method to the Vetronics Tactical Situation Display Maneuver/Navigate application is the map, map overlay and chart. Two examples of the map, map overlay and chart method are reproduced intact from the Prototype Handbook, Section 2.2.4, Methods for Graphics Displays, item e, as follows:

"e. Map, map overlay, and chart. Maps and charts are very versatile forms of graphics displays. Maps usually depict the topographic--the natural and/or manmade--features of a geographic area. The term chart is usually used to refer to navigational maps showing coastlines, water depths, celestial, or other information of use to navigators.

Sample map.

Map overlays permit conversion of a basic map to maps which feature particular aspects of the geographic area, e.g., elevation, rainfall, equipment emplacement. The following figure uses an overlay with symbolic notations to indicate both terrain features and equipment placement.

Sample map overlay."

On-Board Training Module

SUGGESTED FUNCTIONAL DESCRIPTION

Vetronics' automated capabilities provide an opportunity for designing and developing a comprehensive on-board training module with simulated combat conditions. Following the crew's completion of a classroom vehicle training program and demonstration that fundamental combat vehicle operational skills have been acquired, it is advisable that these skills be applied under simulated combat conditions. Application of such operational skills, within a vehicle that is programmed with simulated combat control readouts, provides opportunities for the crew to maximize their skill proficiency level under a variety of conditions.

The training program may be designed as a separate computer training module, that could replace the vehicle's standard operational modules. This training module will be functionally similar to the standard operational modules, with equivalent types of data read into and displayed by the system.

Since combat conditions and consequences (e.g., soldier death) may dictate that crew members take over operational responsibilities not usually assigned to them, such as driving the combat vehicle or shooting the main gun, it is advisable that all crew members be given on-board training experience with all vehicle functions and operations. Thus, regardless of a soldier's intended role on board the combat vehicle, he should strive to be proficient with all vehicle operations. It is therefore recommended that all crew members undergo the identical on-board training program.

The construction of the training programs may be along the following five dimensions:

1. Type of displayed simulated vehicle sensor data.
2. Measurement of crew performance, in response to various combat conditions.
3. Crew performance analyses, with accompanying feedback.

4. Characteristics and intensity of combat scenarios.

5. Graduated experience levels.

Each of these five dimensions is described below.

Simulated Vehicle Sensor Data

A comprehensive simulated combat training package requires that a variety of vehicle sensor data be displayed to reflect differentially orchestrated combat scenarios. The vehicle sensor data will include peripheral sensor data, such as provided by the optical threat detector; and vehicle status data, such as speedometer readings. The various types of simulation combat modules will have different programmed sensor data, to accommodate varying complexity and intensity combat situations and soldier experience levels.

Crew Performance Measurement

In order to monitor the crew's responses to the various combat scenarios, it is necessary to record the crew's performances as they interact/respond to the combat conditions represented by the simulated sensor readings. The following measures are examples of the types of data that may be collected to provide information on crew progress and proficiency level, during the various combat conditions:

1. Reaction time to specific sensor signals.

2. Specific type of response to sensor data.

3. Response sequence (e.g., chain of specific actions such as required to start the vehicle engines).

4. Response amplitude (e.g., voice magnitude).

5. Rate of responding.

Performance Analyses

The effectiveness of training experiences is largely dependent on the analysis and subsequent feedback of crew performance. Thus, it is advisable to use the Vetronics capability for analyzing and providing immediate feed-back to the crew on the accuracy, consistency, and duration of their responses to predetermined, detailed conditions. It can be expected that the quality and reliability of skills will be dependent, to some degree, upon how information (feedback) about past and present performance is transformed into soldier expectations about future behavior (motivation). Subsequent soldier performance is built upon these expectations and goals, and continuously altered and refined.

The evaluation of crew performance consists of comparing their responses with environmental or system quantity and quality standards. These performance outcome or effect criteria include, but are not restricted to:

1. Skill mastery.

2. Knowledge proficiency.

3. Problem solving success.

4. Skill generalizibility (to other tasks, situations, content areas, physical and social environments).

A soldier's conceptualization of the quality and accuracy of his performance is affected by the characteristics of the evaluative performance feedback (reinforcement). Critical feedback elements include, but are not restricted to:

1. Speed. The more promptly feedback is provided after the soldier responds, the greater the opportunity for increased precise learning.

2. Specificity. The more narrowly feedback focuses on the specific soldier response, the more effective it will be.

3. Accuracy. Any imprecision or error in feedback is likely to encourage performance that is contrary to intentions.

4. Content. The information content and media should be appropriate to the desired response. For maintaining alertness and guiding simple responses, bells, lights, and other signals may be appropriate. Complex behavior, such as decision making and problem solving, may require more elaborate information feedback.

5. Amplitude. To be effective in modifying solider responses, feedback must be easily perceived to gain the soldier's attention. However, feedback that is excessive or has emotional implications may actually be disruptive to desired performance.

In addition to using the Vetronics capabilities for the diagnosis and correction of crew performance, under varying simulated combat conditions, the system may be programmed to provide response prompts to the crew. If a solider does not respond to sensor messages or data within a predetermined time, as measured by a timing circuit, appropriate system instructions may be provided to the soldier.

Simulated Combat Scenarios

A comprehensive training program requires that the crew practice the application of their new skills on board the vehicle, under a variety of computer simulated combat conditions. The simulated vehicle sensor data (previously described), would be differentially combined within a number of combat modules to represent a hierarchy of combat scenarios. These combat modules would be designed from the following two dimensional perspective:

1. Combat intensity--e.g., number and degree of enemy signals and attacks.

2. Combat functions--e.g., number and type of crew response actions required.

Soldier Experience Level

In order to accommodate the varying soldier experience and skill levels, the on-board simulated combat modules should be tailored to the novice, as well as the highly skilled crew members. The training modules for the novice crew members would require (1) more system prompts and (2) combat scenarios with less combat intensity and functional responsibilities, thus allowing the novice crew member an opportunity to: (1) practice recently acquired classroom skills under less stressful conditions; (2) receive precise performance feedback; (3) respond to system prompts during periods of response uncertainty; (4) modify and refine response skills as combat scenarios intensify; and (5) gain confidence in response capabilities. As the crew develops experience and skills, the simulated combat scenarios will gradually increase in intensity and complexity.

DERIVED SOLDIER-MACHINE INTERFACE IMPLICATIONS

The on-board training modules require a variety of system input/output components that interface with the crew. To enhance the crew's application of their recently acquired skills on board the combat vehicle, the standard combat vehicle's operational and training modules should be designed to optimize crew members' satisfaction and performance by facilitating the ease of:

1. Obtaining desired information.

2. Locating/interpreting displayed information.

3. Entering commands and instructions for both the standard operational and training modules.

Meeting these design objectives will impact the precision of the crew's activities by reducing:

1. Memory loading. Recall of: characteristics of enemy weapons systems; own vehicle characteristics; own vehicle vulnerability; effect of vehicle weapon systems on enemy equipment; soil characteristics.

2. Perceptual competition. Requirement for attending to displays rather than other aspects of the environment or vehicle operations; requirement for understanding and acting upon displays dealing with a variety of relevant topics.

3. Motor activity requirements. Selecting among different display contents; selecting among different targets.

4. Cognition requirements. Integrating aspects of threat for threat analysis; comparing threat with time to counter threat; assessing the role of countermeasures in threat reduction.

The development of the on-board training modules is directed by the following factors;

1. Issues related to system input:

    a. Personnel characteristics.

    b. Characteristics of combat scenarios.

    c. Type and measurement of specific crew responses.

2. Issues related to system output:

   a. Peripheral and vehicle sensor data.

   b. Crew prompts and instructions.

   c. Crew performance feedback.

Personnel Characteristics

The design of the training modules should incorporate the expected knowledge, skill, and physical characteristics of the standard crew members. Table 3 delineates critical personnel characteristics and accompanying implications for the soldier-machine interface.

Characteristics of Combat Scenarios

The design of a hierarchical set of combat scenarios, respectively reflecting differential degrees of intensity and functional complexity, requires orchestrating a vast quantity of different peripheral and vehicle sensor data. Tables A-1 through A-9 in the Appendix list the types of information that should be incorporated to represent a realistic combat scenario. The novice crew member could practice applying skills with simple on-board training modules that illustrate low combat intensity levels; require focusing attention on one instrument at a time; and necessitate one response at a time. As the crew member gains additional hours of experience on board the vehicle and further assimilates vehicle operational knowledge and skills, more intense and complex combat training modules may be used.

Crew Responses

Since the guidance of system operations will be crew-mediated, numerous human factors principles and guidelines must be considered during the selection of appropriate command media and control methods. For example, many of the command situations which will be encountered during combat vehicle unit operations will require that the crew maintain relatively undivided attention on the display of external sensors. Some form of voice input or simple keypad would appear to be the most appropriate form of input device. However, error rates for voice input and the sound spectrum of the internal vehicle environment may have significant impacts on the viability of the

Table 3

Critical Personnel Characteristics and Accompanying Implications for the Soldier-Machine Interface

PERSONNEL CHARACTERISTIC	IMPLICATIONS FOR SOLDIER-MACHINE INTERFACE
GENERAL EDUCATIONAL LEVEL	• Type of interaction used in the system. • Level of complexity of syntax. • Characteristics of imbedded training systems and features. • Training implications.
INTELLIGENCE AND APTITUDES	• Type of interaction used in the system. • Level and complexity of syntax and grammar. • Amount of memorization required for soldier-computer interaction. • Control device selection. • Characteristics of imbedded training systems and features. • Training implications.
RANGE OF EXPERIENCE IN MILITARY AND CIVILIAN LIFE	• Requirements for tailorable soldier-computer interaction. • Selection among alternative design features to accommodate past soldier experience.
PHYSICAL CHARACTERISTICS ✓ Strength	• Control placement and design. • Workspace configuration.
✓ Dexterity	• Control placement and design. • Workspace layout. • Relationship of Vetronics controls and consoles to other equipment in the vehicle.
✓ Physical size and Anthropometry	• Control placement and design. • Workspace layout. • Relationship of Vetronics controls and consoles to other equipment in the vehicle.

Table 3

(Continued)

PERSONNEL CHARACTERISTICS	IMPLICATIONS FOR SOLDIER-MACHINE INTERFACE
SENSORY CHARACTERISTICS √ Hearing	• Utility of voice output/synthesized speech in Vetronics operation. • Utility of audible signals.
√ Vision ... acuity	• Size of displays. • Characteristics of displayed symbols
√ Vision ... night	• Overall brightness of displays. • Utility of brightness control. • Requirements for feedback controlled display brightness. • Utility of reverse video.
√ Vision ... color	• Utility of color for highlighting and attribute encoding. • Selection of colors for highlighting and attribute encoding. • Permissible density/saturation of colors in displays. • Requirements for alternatives to color for soldier/operator with defective color vision.
SPEECH PATTERNS AND CHARACTERISTICS	• Utility of speech input as a control and data entry device.

voice input approach. Effects of stress on the voices of the crew members may also have a bearing on the acceptability of the voice input approach.

Additionally, the degree of vehicle movement and jostling that may be expected during combat maneuvers, could encourage system developers to maximally reduce the number of terminal keys that must be pressed for specific tactical functions. The high potential for errors to occur, when fine motor movements are required within a turbulent vehicle, may influence system developers to rely on control methods such as light pens and/or joysticks.

To ensure precise measurement, analysis, and feedback of crew functional performance, all fine motor responses, such as pressing terminal keys and light pen movements, should be recorded by the system. Furthermore, any verbal commands to the system could also be documented. These recordings of crew responses will be associated with the specific on-going combat scenarios portrayed by the training module, as well as the respective functional areas. Thus, the documentation for each soldier's response will identify:

1. The general combat situation during the soldier's response.

2. The displayed peripheral and system readings to which the soldier responded.

3. The functional area addressed.

The following list indicates the type of functional areas for which the crew will be responsible:

1. Various control methods.

2. Requests for specific display formats.

3. Data entry procedures.

4. Message composition.

5. Data retrieval.

6. Specific terminology and symbology.

7. Correcting errors.

A cumulative record of crew activities will be maintained by the system and assessed. Comparing soldier responses with predetermined performance criteria will provide measures of the degree of precision, consistency, change, and improvement in soldier performance. Once the crew demonstrates proficiency with the novice level training modules, they will progress to the more advanced simulated combat modules.

Peripheral and Vehicle Sensor Data

The sensor data that will be displayed by the combat vehicle computer system will be combined to portray a hierarchical series of combat scenarios. As previously discussed, Tables A-1 through A-9 list the types of information that will be read/displayed to the crew. The displays will portray combat situations, and require soldier action in response.

Performance Prompts and Instructions

Vetronics has the capability to provide response prompts to novice trainees, as well as to more experienced vehicle operators during periods of memory loss, confusion, fatigue, and/or stress. The number and type of prompts required or requested may be recorded and used during the assessment of crew mastery of vehicle operating procedures.

System prompts and instructions for the crew may be provided via:

1. Aural messages.
2. Textual messages on display screens.
3. Abbreviations or codes via display screens.
4. Series of blinking lights or beeping sounds.

Although battle conditions may preclude the use of aural or extended textual messages, codes and abbreviated textual messages could be useful.

Performance Feedback

Following the recording and analysis of soldier performance against preestablished accuracy and speed criteria, system-generated performance feedback may be communicated to the crew. The types of evaluative feedback might include:

1. Degree of response accuracy.
2. Dichotomous correct or incorrect response assessments.

3. Response consistency or reliability.

4. Response amplitude.

5. Reaction time.

6. Rate of responding.

7. Instant replay or listing of response sequence (e.g., within the past 5 or 10 minutes or since a specific message was displayed).

The system may also be programmed to provide correct responses, once a soldier has been informed of an error. Additional feedback capabilities include notifying the soldier, via textural or graphic representation of the environmental, vehicle, and/or personal ccnsequences of these activities--e.g., soldier's death, combat vehicle exploded, or vehicle weapon successfully exploded another vehicle. The system could also include an instructor "freeze" capability to permit specific live tutorial action. To accentuate the degree of emotionalism affiliated with extreme simulated environmental or personal consequences, flashing red lights or aversive buzzers might be added.

RECOMMENDATIONS

1. Specific soldier-machine interface recommendations cited in the previous section, such as appropriate applications of voice input, light pens, or joysticks, are discussed in greater detail in the Prototype Handbook. Sections of the Prototype Handbook relating to control methods and guidelines that enable system input capabilities for crew members during on-board training include:

   1.1 Alphanumeric Control Methods

   1.2 Graphics Contol Methods

   1.3 HELPs

   3.1 Information on Legal Entries

   3.2 Unburdening of Input

   3.3 Interrupts and Work Recovery

   5.1 Query Method

   5.2 Query Structure

   6.1 Symbols and Symbol Sets

6.2 Standard Terms

6.3 Abbreviations and Codes

6.4 Full Language

7.2 Error Correction and Recovery

2. Sections of the handbook relating to display methods for on-board training modules are:

   2.1 Alphanumeric Displays

   2.2 Graphics Displays

   2.3 Selective Highlighting

   4.1 Composition Aids for Alphanumeric Messages

   4.2 Composition Aids for Graphics Displays

   6.1 Symbols and Symbol Sets

   6.2 Standard Terms

   6.3 Abbreviations and Codes

   7.1 Error Feedback

SUMMARY

This effort to analyze design issues related to the soldier-machine interface of selected of the Vetronics capabilities, and to develop recommendations based on the Prototype Handbook for Combat and Material Developers to resolve a set of SMI issues, has occurred at a very early stage of Vetronics development, without benefit of any design specifications. The analyses presented here are, therefore, tentative; but they nonetheless demonstrate that Vetronics poses considerable SMI issues due to the magnitude and complexity of the data it will handle. Further, the additional tasks Vetronics imposes on the crew are apt to be disruptive to crew performance if they are not fully integrated with current crew responsibilities.

In addition to the volume of data Vetronics will deal with, the volume of transactions anticipated and the nature of the environment in which it will operate, pose increased demands on the soldier's intellectual resources and physical stamina. These conditions require that meaningful, understandable information be presented rapidly and that correct crew interpretations be obtained quickly. Delays caused by the need to ponder an ambiguous display or to deliberate over input commands could lead to the actual destruction of the vehicle and its crew.

The analyses presented here are followed by recommendations for resolution of SMI issues and enhancement of the interface. In addition to specific design recommendations based on content of the Prototype Handbook, more general guidance is provided by suggesting relevant sections of the guidelines document that provide guidance appropriate to recommended transactional features. Table 4 summarizes these Prototype Handbook sections for selected of the intended Vetronics capabilities.

Table 4

Summary of Recommended Guidelines for Soldier-Machine Interface Issues of Selected Vetronics Capabilities

PROTOTYPE HANDBOOK SECTION	VETRONIC CAPABILITY: Manuever/Navigate	System Status	Diagnostics/ Prognostics	BIFF	Tactical Situation Display	On-Board Training Module
1. CONTROL MEASURES						
1.1 Alpahnumeric Control Methods	X	X	X	X	X	X
1.2 Graphics Control Methods	X	X	X	X	X	X
1.3 HELPs		X				X
2. DISPLAY TECHNIQUES						
2.1 Alphanumeric Displays	X	X	X	X	X	X
2.2 Graphics Displays	X	X	X	X	X	X
2.3 Selective Highlighting	X		X	X	X	X
3. DATA ENTRY AND HANDLING						
3.1 Information on Legal Entries			X			X
3.2 Unburdening of Input	X	X		X	X	X
3.3 Interrupts and Work Recovery			X			X
4. MESSAGE COMPOSITION AIDS						
4.1 Composition Aids for Alphanumeric Messages		X	X			X
4.2 Composition Aids for Graphics Displays	X	X				X
5. DATA RETRIEVAL ASSISTANCE						
5.1 Query Method	X	X			X	X
5.2 Query Structure		X				X
6. SYMBOLOGY AND TERMINOLOGY						
6.1 Symbols and Symbol Sets	X	X	X	X	X	X
6.2 Standard Terms		X	X			X
6.3 Abbreviations and Codes		X	X	X	X	X
6.4 Full Language						X
6.5 Glossaries						
7. ERROR HANDLING						
7.1 Error Feedback	X	X		X	X	X
7.2 Error Correction and Recovery	X	X		X	X	X

APPENDIX

Table A-1.

Data Pertaining to Meteorological Conditions

SPECIFIC ELEMENT OR ATTRIBUTE OF DATA	UTILITY OF DATA TO COMBAT VEHICLE CREWS	DATA SOURCE							
		STORED IN VEHICLE	VEHICLE SENSORS (INT.)	VEHICLE SENSORS (EXT.)	VEHICLE UNIT COMMO	LOCAL/REMOTE SENSOR	DIRECT DOWNLINK	REMOTE SYSTEM COMMO	DERIVATIVE (PROCESS)
RAIN: Recent History	• Route planning	•						•	
	• Maneuver control	•						•	
	• Terrain exploitation	•						•	
Current	• Threat assessment	•		•					•
	• Counter measure selection	•		•					•
	• Target selection			•					•
	• Terrain exploitation			•					•
	• Target acquisition	•		•					•
	• Fire control	•		•					•
Forecast	• Route planning	•						•	
	• Maneuver control	•						•	
TEMPERATURE: Recent history	• Route planning	•						•	
	• Maneuver control	•						•	
	• Threat assessment	•						•	
Current	• Fire control			•					
	• Target acquisition			•					
Forecast	• Route planning	•						•	
	• Maneuver control	•						•	

Table A-1.

(Continued)

SPECIFIC ELEMENT OR ATTRIBUTE OF DATA	UTILITY OF DATA TO COMBAT VEHICLE CREWS	DATA SOURCE							
		STORED IN VEHICLE	VEHICLE SENSORS (INT.)	VEHICLE SENSORS (EXT.)	VEHICLE UNIT COMMO	LOCAL/REMOTE SENSOR	DIRECT DOWNLINK	REMOTE SYSTEM COMMO	DERIVATIVE (PROCESS)
SNOW: Recent History	• Route planning	●						●	
	• Maneuver control	●						●	
Current	• Threat assessment			●					
	• Counter measure selection			●					
	• Target selection			●					
	• Terrain exploitation			●					
	• Target acquisition			●					
	• Fire control			●					
Forecast	• Route planning	●						●	
	• Maneuver control	●						●	
CURRENT WIND	• Counter measure selection			●					
	• Target acquisition			●					
	• Fire control			●					
	• Target selection			●					
CURRENT FOG/SMOG	• Terrain exploitation			●					
	• Target acquisition			●					
	• Counter measure selection			●					
	• Fire control			●					

Table A-1.

(Continued)

SPECIFIC ELEMENT OR ATTRIBUTE OF DATA	UTILITY OF DATA TO COMBAT VEHICLE CREWS	DATA SOURCE: STORED IN TANK	VEHICLE SENSORS (INT.)	VEHICLE SENSORS (EXT.)	VEHICLE UNIT COMMO	LOCAL/REMOTE SENSOR	DIRECT DOWNLINK	REMOTE SYSTEM COMMO	DERIVATIVE (PROCESS)
CURRENT HUMIDITY	• Fire control			●					
	• Target acquisition			●					
CURRENT BAROMETRIC PRESSURE	• Fire control			●					
	• Target acquisition			●					

Table A-2.

Data Pertaining to Environmental Conditions

INFORMATION TYPE	INFORMATION ATTRIBUTES	SOLDIER-SYSTEM INTERFACE APPLICATIONS
NOISE	• Intensity	• Feasibility of audible alarms and signals • Required levels of audible alarms and signals
	• Spectral characteristics	• Optimum frequency for audible alarms and signals • Filler characteristics for voice input • Spectrum for voice output
	• Duration; continuousness; predictability	• Requirements for multiple input/output channels
SMOKE; HAZE	• Density	• Required intensity of visual displays • Operator-to-display distance limits
	• Persistence	• Requirements for varying display intensity levels
	• Spectral characteristics (reflection; absorbtion)	• Required color of visual displays
TEMPERATURE	• Level	• Design of controls to accommodate to physical concommitants of temperature extremes: — Perspiration — Stiff, numb fingers and other extremities
	• Stability	• Requirements for design of controls and displays to accommodate a wide range of physical concommitants of temperature extremes
LIGHTING	• Intensity	• Required intensity of visual displays
	• Source	• Arrangements of visual displays to eliminate/reduce "washout" • Requirements for reorientability of visual displays to accommodate changing illumination sources
	• Spectral characteristics	• Requirements for color of visual displays • Requirements for color of reflected-light markings on controls and instructions • Requirements for color of printed job aids
	• Duration; continuousness; predictability	• Requirements for variability in display intensity and orientation • Requirements for automated control of display intensity and orientation • Requirements for variability in control illumination

Table A-2.

(Continued)

INFORMATION TYPE	INFORMATION ATTRIBUTES	SOLDIER-SYSTEM INTERFACE APPLICATIONS
VIBRATION	• Intensity (amplitude)	• Requirements for type and size of displays • Requirements for design and installation of control devices
	• Period (spectral charactistics)	• Requirements for type and size of displays (and elements of displays) • Requirements for design and installation of control devices
	• Duration; continuousness; predictability	• Requirements for variability in display element size • Requirements for automated control of display element size • Requirements for default display to particular device during periods of high vibration
ACCELERATION	• Intensity	• Requirements for control selection and design • Requirements for display positioning
	• Duration; continuousness; predictability	• Requirements for control selection and design • Requirements for display positioning • Requirements for acceleration--induced error correction • Requirements for real-time detection of acceleration forces and associated suspension/alteration of display/control/processing activities • Requirements for alternative display/control modes
	• Direction	• Control positioning requirements • Display positioning requirements

Table A-3.

Data Pertaining to Plans, Routes, and Missions

SPECIFIC ELEMENT OR ATTRIBUTE OF DATA	UTILITY OF DATA TO COMBAT VEHICLE CREWS	DATA SOURCE: STORED IN VEHICLE	VEHICLE SENSORS (INT.)	VEHICLE SENSORS (EXT.)	VEHICLE UNIT COMMO	LOCAL/REMOTE SENSOR	DIRECT DOWNLINK	REMOTE SYSTEM COMMO	DERIVATIVE (PROCESS)
BATTLE PLAN	• Route planning	●						●	
	• Scheduling	●						●	
	• Schedule adherence analysis	●						●	
	• Targeting priority assignment	●						●	
OBJECTIVES	• Route planning	●						●	
	• Alternative route analysis	●						●	
	• Schedule adherence analysis	●						●	
	• Maneuver control	●						●	
TARGETS	• Targeting	●						●	
CONTINGENCY PLANS	• Route planning	●						●	
	• Assignment of resources	●						●	
	• Rescheduling	●						●	
	• Time-to-point estimation	●						●	
RULES OF ENGAGEMENT	• Target priority assignment	●						●	
	• Target selection	●						●	

Table A-4.

Data Pertaining to Individual Combat Vehicles

SPECIFIC ELEMENT OR ATTRIBUTE OF DATA	UTILITY OF DATA TO COMBAT VEHICLE CREWS	DATA SOURCE							
		STORED IN VEHICLE	VEHICLE SENSORS (INT.)	VEHICLE SENSORS (EXT.)	VEHICLE UNIT COMMO	LOCAL/REMOTE SENSOR	DIRECT DOWNLINK	REMOTE SYSTEM COMMO	DERIVATIVE (PROCESS)
POSITION	• Route planning • Target selection • Target acquisition • Terrain masking • Analysis of terrain attributes		●						
BEARING	• Warning of terrain conflict • Orientation' re other forces *Friendly *Enemy • Point arrival prediction • Target selection • Target acquisition		●						●
VELOCITY	• Route planning • Timely warning of terrain conflict • Warning of exposure to enemy fire • Point arrival prediction • Time to refueling • Target selection (predictive) • Target acquisition • Target tracking		●						●

Table A-4.

(Continued)

SPECIFIC ELEMENT OR ATTRIBUTE OF DATA	UTILITY OF DATA TO COMBAT VEHICLE CREWS	DATA SOURCE							
		STORED IN VEHICLE	VEHICLE SENSORS (INT.)	VEHICLE SENSORS (EXT.)	VEHICLE UNIT COMMO	LOCAL/REMOTE SENSOR	DIRECT DOWNLINK	REMOTE SYSTEM COMMO	DERIVATIVE (PROCESS)
ATTITUDE Roll Pitch Yaw	• Target acquisition • Target tracking • Assessment of tank performance envelope performance • Maneuver planning • Weapons resource allocation • Fire control		•						
WEAPONS SYSTEM STATUS: Operability	• Weapons system resource allocation • Fire control • Target selection • Target acquisition		•						
Orientation (Asimuth/ Elevation)	• Target selection • Target acquisition • Fire control		•						
Temperature	• Target acquisition • Fire control		•						
Ammo Loaded	• Target selection • Target acquisition • Fire control		•						

Table A-4.

(Continued)

SPECIFIC ELEMENT OR ATTRIBUTE OF DATA	UTILITY OF DATA TO COMBAT VEHICLE CREWS	DATA SOURCE							
		STORED IN VEHICLE	VEHICLE SENSORS (INT.)	VEHICLE SENSORS (EXT.)	VEHICLE UNIT COMMO	LOCAL/REMOTE SENSOR	DIRECT DOWNLINK	REMOTE SYSTEM COMMO	DERIVATIVE (PROCESS)
SENSOR STATUS: Operability	• Allocation of personnel and processing resources • Threat assessment • Threat/information tradeoff		●						
Orientation/ Aim	• Allocation of personnel and processing tradeoffs • Target identification • Target acquisition • Target selection		●						
Performance	• Threat assessment • Selection of most appropriate data source		●						
PROPULSION SYSTEM STATUS: Temperature	• Route planning • Maneuver planning • Time to reach designated point • Predicted system failure point		●						
Fuel Flow	• Operating radius • Predicted vs. actual performance • Route planning • Maneuver planning • Maintenance indicator		●						

Table A-4.

(Continued)

SPECIFIC ELEMENT OR ATTRIBUTE OF DATA	UTILITY OF DATA TO COMBAT VEHICLE CREWS	DATA SOURCE							
		STORED IN VEHICLE	VEHICLE SENSORS (INT.)	VEHICLE SENSORS (EXT.)	VEHICLE UNIT COMMO	LOCAL/REMOTE SENSOR	DIRECT DOWNLINK	REMOTE SYSTEM COMMO	DERIVATIVE (PROCESS)
PROPULSION SYSTEM STATUS (Cont.): Mixture	• Operating radius • Predicted vs. actual tank performance • Maintenance indicator		●						
COMMUNICATION SYSTEM STATUS: Operability	• Route planning • Maneuver planning • Assessment of onboard information timeliness		●	●				●	
BIFF	• Target identification • Target selection		●						
Utilization	• Time/information requirement tradeoffs		●						
TRACTION	• Route planning • Maneuver.planning • Indication of error in mobility, time-to-location, and operating radius estimates		●						
COUNTERMEASURES STATUS: Operability	• Threat assessment • Target selection • Route planning • Maneuver planning • Maneuver control		●						

Table A-4.

(Continued)

SPECIFIC ELEMENT OR ATTRIBUTE OF DATA	UTILITY OF DATA TO COMBAT VEHICLE CREWS	DATA SOURCE: STORED IN VEHICLE	VEHICLE SENSORS (INT.)	VEHICLE SENSORS (EXT.)	VEHICLE UNIT COMMO	LOCAL/REMOTE SENSOR	DIRECT DOWNLINK	REMOTE SYSTEM COMMO	DERIVATIVE (PROCESS)
COUNTERMEASURES STATUS (Cont.) Orientation/ Aim	• Threat assessment • Target selection • Maneuver control		●						
Load	• Threat assessment • Target selection • Maneuver planning/control		●						
ELECTRICAL & ELECTRONICS SYSTEMS STATUS: Availability	• Threat assessment • Personnel/processor tasking • Decision process allocation • Capabilities assessment and prediction		●						
AMMUNITION STATUS: Available Types	• Target selection • Maneuver planning and control • Route planning • Weapons resource allocation		●						
Amount	• Target selection • Maneuver planning and control • Route planning • Weapons resource allocation		●						
AMMUNITION STATUS: Usage Rate	• Estimation of useful operational radius and tenure • Route planning • Target selection • Maneuver planning and control		●						

Table A-4.

(Continued)

SPECIFIC ELEMENT OR ATTRIBUTE OF DATA	UTILITY OF DATA TO COMBAT VEHICLE CREWS	DATA SOURCE							
		STORED IN VEHICLE	VEHICLE SENSORS (INT.)	VEHICLE SENSORS (EXT.)	VEHICLE UNIT COMMO	LOCAL/REMOTE SENSOR	DIRECT DOWNLINK	REMOTE SYSTEM COMMO	DERIVATIVE (PROCESS)
FUEL, LUBRICANT, AND COOLANT: Amount	• Estimation of operational radius and tenure • Route planning • Maintenance planning • Maneuver planning and control		•						
Usage Rate	• Estimation of operational radius and tenure • Route planning • Maintenance planning • Maneuver planning and control		•						
VEHICLE PERFORMANCE CAPABILITIES Speed Manauverability Grades Trenches Range Attitude	• Comparison to actual vehicle behavior • Comparison to terrain • Real-time comparison with vehicle situation	•							

Table A-4.

(Continued)

SPECIFIC ELEMENT OR ATTRIBUTE OF DATA	UTILITY OF DATA TO COMBAT VEHICLE CREWS	DATA SOURCE: STORED IN VEHICLE	VEHICLE SENSORS (INT.)	VEHICLE SONSORS (EXT.)	VEHICLE UNIT COMMO	LOCAL/REMOTE SENSOR	DIRECT DOWNLINK	REMOTE SYSTEM COMMO	DERIVATIVE (PROCESS)
WEAPON PERFORMANCE CAPABILITIES: •Train Rate •Elevation •Range •Accuracy •Kill Prob. •Target Type Dependencies	• Target selection • Maneuver control • Terrain utilization/avoidance • Route planning	●							
DEFENSIVE SYSTEM PERFORMANCE CAPABILITIES: •Armor Effectiveness •Jamming •Other	• Route planning • Target selection • Maneuver control	●							

Table A-5.

Data Pertaining to Combat Vehicle Platoon or Other Unit

SPECIFIC ELEMENT OR ATTRIBUTE OF DATA	UTILITY OF DATA TO COMBAT VEHICLE CREWS	DATA SOURCE							
		STORED IN VEHICLE	VEHICLE SENSORS (INT.)	VEHICLE SENSORS (EXT.)	VEHICLE UNIT COMMO	LOCAL/REMOTE SENSOR	DIRECT DOWNLINK	REMOTE SYSTEM COMMO	DERIVATIVE (PROCESS)
MISSION DATA: Objective Location	• Route planning	●			●			●	
	• Mission planning	●			●				
	• Maneuver control	●			●			●	
Objective Type	• Weapons allocation	●							
	• Target acquisition	●							
Primary Route	• Route planning	●							
	• Performance envelope planning	●							
Alternative Routes	• Route planning	●							
	• Performance envelope planning	●							
Critical Maneuver Points	• Route planning	●				●	●	●	
	• Maneuver planning	●				●	●	●	
	• Contingency route planning	●				●	●	●	
POSITION RELATIVE TO OTHER VEHICLES	• Maneuver control		●		●				●
	• Joint target selection		●		●				●
	• Target identification		●		●				●
	• Sensor optimization		●		●				●
FIELD OF FIRE	• Joint target selection	●	●		●				●
	• Threat evaluation	●	●		●				●

Table A-5.

(Continued)

SPECIFIC ELEMENT OR ATTRIBUTE OF DATA	UTILITY OF DATA TO COMBAT VEHICLE CREWS	DATA SOURCE: STORED IN VEHICLE	VEHICLE SENSORS (INT.)	VEHICLE SENSORS (EXT.)	VEHICLE UNIT COMMO	LOCAL/REMOTE SENSOR	DIRECT DOWNLINK	REMOTE SYSTEM COMMO	DERIVATIVE (PROCESS)
VEHICLE UNIT COMPOSITE STATUS: Weapons System	• Target selection		●		●				
	• Maneuver planning and control		●		●				
	• Resource allocation		●		●				
	• Tank placement and assignment		●		●				
Sensor Systems	• Target selection		●		●				
	• Maneuver planning and control		●		●				
	• Route planning		●		●				
	• Threat assessment		●		●				
Counter-measure Status	• Maneuver planning and control		●		●				
	• Route planning		●		●				
	• Threat assessment		●		●				
Position and Orientation	• Target selection		●	●	●				
	• Joint target acquisition		●	●	●				
	• Maneuver planning and control		●	●	●				
	• Terrain capitalization	●	●	●	●				●
Electrical & Electronics System Status	• Target selection	O	●	O	●	O	O	O	O
	• Threat assessment	O	●	O	●	O	O	O	O
	• Maneuver planning and control	O	●	O	●	O	O	O	O
	• Vehicle placement and role assignment	O	●	O	●	O	O	O	O

Table A-5.

(Continued)

SPECIFIC ELEMENT OR ATTRIBUTE OF DATA	UTILITY OF DATA TO COMBAT VEHICLE CREWS	DATA SOURCE							
		STORED IN VEHICLE	VEHICLE SENSORS (INT.)	VEHICLE SENSORS (EXT.)	VEHICLE UNIT COMMO	LOCAL/REMOTE SENSOR	DIRECT DOWNLINK	REMOTE SYSTEM COMMO	DERIVATIVE (PROCESS)
VEHICLE UNIT COMPOSITE STATUS (Cont.): Propulsion System Status	• Threat assessment		●		●				
	• Maneuver planning and control		●		●				
	• Vehicle placement and assignment		●		●				
	• Target selection		●		●				
Ammunition Status	• Threat assessment		●		●				
	• Target selection		●		●				
	• Vehicle placement and assignment		●		●				
Communication Status	• Target selection		●		●				
	• Vehicle placement and assignment		●		●				
	• Default operations		●		●				

Table A-6.

Data Pertaining to Friendly Forces

SPECIFIC ELEMENT OR ATTRIBUTE OF DATA	UTILITY OF DATA TO COMBAT VEHICLE CREWS	DATA SOURCE: STORED IN VEHICLE	DATA SOURCE: VEHICLE SENSORS (INT.)	DATA SOURCE: VEHICLE SENSORS (EXT.)	DATA SOURCE: VEHICLE UNIT COMMO	DATA SOURCE: LOCAL/REMOTE SENSOR	DATA SOURCE: DIRECT DOWNLINK	DATA SOURCE: REMOTE SYSTEM COMMO	DATA SOURCE: DERIVATIVE (PROCESS)
TYPE OF FORCE OR EQUIPMENT: Infantry, Armor, Artillery, ADA, Anti-tank, Helo, FW A/C, Sensors, Log/Supply	• Mission planning and execution • Route planning • Threat assessment • Target selection • Target identification	●						●	
POSITION	• Route planning	●						●	
	• Threat assessment	●		●			●	●	
	• Target identification	●		●			●	●	
	• Target selection	●		●			●	●	
	• Fire control	●		●			●	●	
SPEED	• Threat assessment			●					
	• Target identification	●		●					●
	• Fire control			●					

Table A-6.

(Continued)

SPECIFIC ELEMENT OR ATTRIBUTE OF DATA	UTILITY OF DATA TO TANK CREWS	DATA SOURCE: STORED IN VEHICLE	VEHICLE SENSORS (INT.)	VEHICLE SENSORS (EXT.)	VEHICLE UNIT COMMO	LOCAL/REMOTE SENSOR	DIRECT DOWNLINK	REMOTE SYSTEM COMMO	DERIVATIVE (PROCESS)
BEARING	• Threat assessment	●		●				●	●
	• Fire control	●		●				●	●
	• Route planning	●						●	
	• Maneuver planning and control	●		●				●	●
ASSOCIATED EQUIPMENT:	• Mission coordination	●						●	
Weapons Commo	• Threat assessment	●		●		●	●	●	●
Sensors Supplies	• Target selection	●		●		●	●	●	●
	• Route and maneuver control	●				●	●	●	

Table A-7.

Data Pertaining to Enemy Forces

SPECIFIC ELEMENT OR ATTRIBUTE OF DATA	UTILITY OF DATA TO COMBAT VEHICLE CREWS	DATA SOURCE: STORED IN VEHICLE	VEHICLE SENSORS (INT.)	VEHICLE SENSORS (EXT.)	VEHICLE UNIT COMMO	LOCAL/REMOTE SENSOR	DIRECT DOWNLINK	REMOTE SYSTEM COMMO	DERIVATIVE (PROCESS)
TYPE OF FORCE/ EQUIPMENT: Armor, Helo, Artillery, Infantry, Anti-tank, FW A/C, Sensors, Supply, ADA	• Route planning	●				●	●	●	
	• Maneuver planning and control	●		●		●	●	●	
	• Target selection	●		●					
	• Threat assessment	●		●					
	• Terrain exploitation	●		●					
POSITION	• Route planning	●							
	• Threat assessment			●	O	O	O	O	
	• Target identification			●	O	O	O	O	
	• Target selection			●	O	O	O	O	
	• Target acquisition			●	O	O	O	O	
	• Fire control			●	O	O	O	O	
	• Terrain exploitation			●	O	O	O	O	
SPEED	• Maneuver planning and control	●		●					
	• Threat assessment	●		●					
	• Target identification	●		●					
	• Target selection			●					
	• Target acquisition			●					
	• Fire control			●					
	• Terrain exploitation	●		●					

Table A-7.

(Continued)

SPECIFIC ELEMENT OR ATTRIBUTE OF DATA	UTILITY OF DATA TO COMBAT VEHICLE CREWS	DATA SOURCE							
		STORED IN VEHICLE	VEHICLE SENSORS (INT.)	VEHICLE SENSORS (EXT.)	VEHICLE UNIT COMMO	LOCAL/REMOTE SENSOR	DIRECT DOWNLINK	REMOTE SYSTEM COMMO	DERIVATIVE (PROCESS)
BEARING	• Threat assessment			●		●	●	●	
	• Target identification			●		●	●	●	
	• Target selection			●		●	●	●	
	• Target acquisition			●		●	●	●	
	• Fire control			●		●	●	●	
	• Terrain exploitation			●		●	●	●	
PROJECTED POSITION	• Maneuver control			●		●	●	●	●
	• Threat assessment			●		●	●	●	
	• Route planning			●		●	●	●	
	• Fire control			●		●	●	●	
	• Target acquisition			●		●	●	●	
WEAPONRY: Range	• Maneuver control	●		●					
	• Threat assessment	●		●					
	• Terrain exploitation	●		●					
Rate of Fire	• Maneuver control	●		●					
	• Threat assessment	●		●					
	• Terrain exploitation	●		●					
Accuracy	• Threat assessment	●		●					
	• Terrain exploitation	●		●					

Table A-7.

(Continued)

SPECIFIC ELEMENT OR ATTRIBUTE OF DATA	UTILITY OF DATA TO COMBAT VEHICLE CREWS	DATA SOURCE: STORED IN VEHICLE	DATA SOURCE: VEHICLE SENSORS (INT.)	DATA SOURCE: VEHICLE SENSORS (EXT.)	DATA SOURCE: VEHICLE UNIT COMMO	DATA SOURCE: LOCAL/REMOTE SENSOR	DATA SOURCE: DIRECT DOWNLINK	DATA SOURCE: REMOTE SYSTEM COMMO	DATA SOURCE: DERIVATIVE (PROCESS)
WEAPONRY (Cont.): Accuracy (Cont.):	• Maneuver control	●		●					
	• Target selection	●		●					
Orientation	• Threat assessment			●		●	●		
	• Target selection			●		●	●		
	• Terrain exploitation			●		●	●		
Reaction/ Response	• Terrain exploitation	●		●	●				
	• Threat assessment	●		●	●				
	• Target selection	●		●	●				
Associated Sensors/Fire Control	• Threat assessment	●		●	●				
	• Target selection	●		●	●				
	• Cover exploitation	●		●	●				
	• Sensor utilization	●		●	●				
	• Countermeasures employment	●		●	●				
VEHICLE/PLATFORM CAPABILITIES: Speed	• Threat projection/assessment	●							
	• Position projection	●							
	• Terrain exploitation	●							
	• Maneuver control	●							
	• Target selection	●							

Table A-7.

(Continued)

SPECIFIC ELEMENT OR ATTRIBUTE OF DATA	UTILITY OF DATA TO COMBAT VEHICLE CREWS	DATA SOURCE: STORED IN VEHICLE	VEHICLE SENSORS (INT.)	VEHICLE SENSORS (EXT.)	VEHICLE UNIT COMMO	LOCAL/REMOTE SENSOR	DIRECT DOWNLINK	REMOTE SYSTEM COMMO	DERIVATIVE (PROCESS)
VEHICLE/PLATFORM CAPABILITIES (Cont.): Maneuverability	• Threat assessment	●							
	• Position projection	●							
	• Weapons orientation	●							
Vulnerability	• Threat assessment	●							
	• Weapons allocation	●							
	• Target selection	●							
Number	• Route planning			●	●			●	
	• Threat assessment			●	●			●	
	• Target selection			●	●			●	
SENSOR CHARACTERISTICS AND CAPABILITIES: Type: Optical, Laser, Radar, Acoustic, Magnetic, Thermal	• Route planning	●		●	●				
	• Maneuver control	●		●	●				
	• Terrain exploitation	●		●	●				
	• Cover exploitation	●		●	●				
	• Countermeasures application	●		●	●				
	• Target identification	●		●	●				
	• Target selection	●		●	●				
	• Target acquisition								

Table A-7.

(Continued)

SPECIFIC ELEMENT OR ATTRIBUTE OF DATA	UTILITY OF DATA TO COMBAT VEHICLE CREWS	DATA SOURCE							
		STORED IN VEHICLE	VEHICLE SENSORS (INT.)	VEHICLE SENSORS (EXT.)	VEHICLE UNIT COMMO	LOCAL/REMOTE SENSOR	DIRECT DOWNLINK	REMOTE SYSTEM COMMO	DERIVATIVE (PROCESS)
SENSOR CHARACTERISTICS AND CAPABILITIES (Cont.): Range	• Route planning	●							
	• Maneuver control	●							
	• Target selection	●							
	• Threat assessment	●							
	• Terrain exploitation	●							
Vulnerability to Countermeasures	• Countermeasures utilization	●							
	• Maneuver control	●							
Position	• Route planning			●	●	●			
	• Maneuver control			●	●	●			
	• Threat assessment			●	●	●			
	• Terrain exploitation			●	●	●			
	• Cover exploitation			●	●	●			
	• Countermeasures application			●	●	●			
	• Target identification			●	●	●			
	• Target selection			●	●	●			
	• Target acquisition			●	●	●			
	• Fire control			●	●	●			
UNIT DESIGNATION	• Route planning								
	• Maneuver control								
	• Threat assessment								

Table A-8.

Data Pertaining to External Physical Environment

SPECIFIC ELEMENT OR ATTRIBUTE OF DATA	UTILITY OF DATA TO COMBAT VEHICLE CREWS	DATA SOURCE							
		STORED IN VEHICLE	VEHICLE SENSORS (INT.)	VEHICLE SENSORS (EXT.)	VEHICLE UNIT COMMO	LOCAL/REMOTE SENSOR	DIRECT DOWNLINK	REMOTE SYSTEM COMMO	DERIVATIVE (PROCESS)
RADIO:	• Threat assessment	•		•					
Frequency	• Target identification	•		•					
Intensity	• Maneuver control			•					
	• Route Planning			•					
	• Target selection			•					
	• Target acquisition			•					
	• Weapons orientation			•					
Bearing	• Route planning			•					
	• Maneuver control			•					
	• Target selection			•					
	• Target acquisition			•					
	• Weapons orientation			•					
Modulation Characteristics	• Target identification	•		•					
	• Threat assessment	•		•					
RADAR: Frequency or Band	• Target identification	•		•					
	• Threat assessment	•		•					
Modulation Characteristic	• Target identification	•		•					
	• Threat assessment	•		•					

Table A-8.

(Continued)

SPECIFIC ELEMENT OR ATTRIBUTE OF DATA	UTILITY OF DATA TO COMBAT VEHICLE CREWS	DATA SOURCE: STORED IN VEHICLE	VEHICLE SENSORS (INT.)	VEHICLE SENSORS (EXT.)	VEHICLE UNIT COMMO	LOCAL/REMOTE SENSOR	DIRECT DOWNLINK	REMOTE SYSTEM COMMO	DERIVATIVE (PROCESS)
RADAR (cont.): Sweep/Scan Rate	• Target identification	●		●					
	• Threat assessment	●		●					
Intensity	• Route planning			●					
	• Maneuver control			●					
	• Target selection			●					
	• Target identification	●		●					
	• Counter measures selection	●		●					
Bearing (Vector to source)	• Route planning			●					
	• Maneuver control			●					
	• Target selection			●					
	• Target acquisition			●					
	• Weapons orientation			●					
	• Countermeasures orientation			●					
INFRARED RADIATION: Frequency Distribution	• Target identification	●		●					
	• Threat assessment	●		●					
Intensity	• Target identification	●		●					
	• Threat assessment	●		●					

Table A-8.

(Continued)

SPECIFIC ELEMENT OR ATTRIBUTE OF DATA	UTILITY OF DATA TO COMBAT VEHICLE CREWS	DATA SOURCE: STORED IN VEHICLE	VEHICLE SENSORS (INT.)	VEHICLE SENSORS (EXT.)	VEHICLE UNIT COMMO	LOCAL/REMOTE SENSOR	DIRECT DOWNLINK	REMOTE SYSTEM COMMO	DERIVATIVE (PROCESS)
INFRARED RADIATION(cont):	• Route planning			•					
Bearing	• Maneuver planning			•					
	• Target selection			•					
	• Target acquisition			•					
	• Weapons orientation			•					
	• Countermeasures selection			•					
	• Countermeasures orientation			•					
Motion	• Target identification	•		•					•
	• Threat assessment	•		•					•
	• Weapons selection			•					•
	• Weapon orientation			•					•
	• Target selection			•					•
	• Target acquisition			•					•
	• Countermeasures selection	•		•					•
	• Countermeasures orientation	•		•					•
	• Fire control			•					•
LIGHT:	• Maneuver control	•		•					
Coherence	• Target identification	•		•					
	• Threat assessment	•		•					
	• Countermeasures selection	•		•					

Table A-8.

(Continued)

SPECIFIC ELEMENT OR ATTRIBUTE OF DATA	UTILITY OF DATA TO COMBAT VEHICLE CREWS	DATA SOURCE: STORED IN VEHICLE	VEHICLE SENSORS (INT.)	VEHICLE SENSORS (EXT.)	VEHICLE UNIT COMMO	LOCAL/REMOTE SENSOR	DIRECT DOWNLINK	REMOTE SYSTEM COMMO	DERIVATIVE (PROCESS)
LIGHT (cont.):	• Target identification	●		●					
Frequencies	• Threat assessment	●		●					
Bearing	• Route planning			●					
	• Maneuver planning			●					
	• Target selection			●					
	• Target acquisition			●					
	• Weapons orientation			●					
	• Weapons selection			●					
	• Countermeasures selection			●					
	• Countermeasures orientation			●					
	• Fire control			●					
IONIZING RADIATION: Type: Alpha Beta Neutron	• Threat assessment	●		●					
	• Counter measures selection	●		●					
	• Route planning	●		●					
Level	• Threat assessment	●		●					●
	• Countermeasures selection	●		●					●
	• Route & maneuver planning	●		●					●
Bearing	• Route planning			●					
	• Maneuver control			●					

Table A-8.

(Continued)

SPECIFIC ELEMENT OR ATTRIBUTE OF DATA	UTILITY OF DATA TO COMBAT VEHICLE CREWS	DATA SOURCE: STORED IN VEHICLE	VEHICLE SENSORS (INT.)	VEHICLE SENSORS (EXT.)	VEHICLE UNIT COMMO	LOCAL/REMOTE SENSOR	DIRECT DOWNLINK	REMOTE SYSTEM COMMO	DERIVATIVE (PROCESS)
ACOUSTIC ENERGY:	• Target identification	●		●					
Spectrum	• Threat assessment	●		●					
Intensity	• Threat assessment			●					
	• Weapons orientation			●					
	• Target selection			●					
Stability/ Duration	• Threat assessment			●					●
Bearing	• Route planning			●					
	• Maneuver control			●					
	• Target selection			●					
	• Weapons orientation			●					
	• Weapon selection			●					

Table A-9.

Data Pertaining to Topography/Terrain

SPECIFIC ELEMENT OR ATTRIBUTE OF DATA	UTILITY OF DATA TO COMBAT VEHICLE CREWS	DATA SOURCE: STORED IN VEHICLE	VEHICLE SENSORS (INT.)	VEHICLE SENSORS (EXT.)	VEHICLE UNIT COMMO	LOCAL/REMOTE SENSOR	DIRECT DOWNLINK	REMOTE SYSTEM COMMO	DERIVATIVE (PROCESS)
TERRAIN ELEVATION	• Route planning	●							
	• Maneuver planning	●							
	• Alternative route analysis	●							
	• Fuel use estimation	●							
	• Terrain masking analysis	●							
	• Threat warning analysis	●							
	• Weapons orientation	●							
	• Sensor orientation	●							
	• Countermeasures orientation	●							
	• Fire control	●							
MANEUVER-RELEVANT TERRAIN FEATURES	• Route planning	●							
	• Alternative route analysis	●							
Rivers, Lakes Marshes, Swamps Wooded Areas Sand Trenches, Gullies Fords Open Areas Glaciers									

Table A-9.

(Continued)

SPECIFIC ELEMENT OR ATTRIBUTE OF DATA	UTILITY OF DATA TO COMBAT VEHICLE CREWS	DATA SOURCE							
		STORED IN VEHICLE	VEHICLE SENSORS (INT.)	VEHICLE SENSORS (EXT.)	VEHICLE UNIT COMMO	LOCAL/REMOTE SENSOR	DIRECT DOWNLINK	REMOTE SYSTEM COMMO	DERIVATIVE (PROCESS)
MANEUVER-RELEVANT CULTURAL FEATURES	• Route planning	●				●	●	●	
	• Alternative route analysis	●				●	●	●	
Bridges Roads Railroads Walls/Abutments									
SOIL TYPE	• Route planning	●							
	• Alternative route analysis	●							
	• Fuel consumption	●							
	• Time-to-point estimation	●							
CULTURAL & LANDMARK FEATURES	• Route planning	●				●	●	●	
	• Alternative route analysis	●				●	●	●	

SECTION 2

SOLDIER/MACHINE ISSUES IN THE DESIGN OF THE VIDS-DMS

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SUMMARY 66

Organization of the Report

Part 1 provides an overview of the VIDS-DMS for the benefit of readers who are not familiar with the system. Part 2, Analysis and General Findings, describes the techniques used to analyze the system's software modiles and processes and discusses global issues in the design of the soldier/machine interface. Part 3, Modules and Processes, addresses each module or process separately, presenting a brief functional description, implications for the soldier/machine interface and recommendations to resolve design issues. Part 4 contains a summary of design issues and recommendations.

Overview of the VIDS-DMS

The US Army Development and Readiness Command (DARCOM), through the Concepts Laboratory at the Research and Development Center of its Tank-Automotive Command (TACOM), is developing self-protection systems for ground combat vehicles. The focus of this effort is the Vehicle Integrated Defense System - Data Management System (VIDS-DMSO) whose general design concept is illustrated in Figure 1. Current plans call for the design, development, and test of a Feasibility Demonstration Model (FDM) of the VIDS-DMS, which will emphasize the data management aspects of the system. The DMS will provide a data processing and distribution system to coordinate the VIDS's threat warning sensors, threat reaction devices, and crew interaction subsystems. Signals from the system's sensors will be processed to detect, locate, and classify threats. Self-protection algorithms will compare these threats against standards and priorities stored in internal files and tables.

Other algorithms, containing recommended reactions as well as threat classification and locations information, will display warnings to the crew. The crew in turn will instruct the DMS to initiate countermeasures, either by approving the system's recommendation or by specifying another reaction. In the FDM, sensor inputs and reaction outputs will be simulated to provide a feasibility demonstration. In addition, available devices will be used to simulate the crew display and control unit.

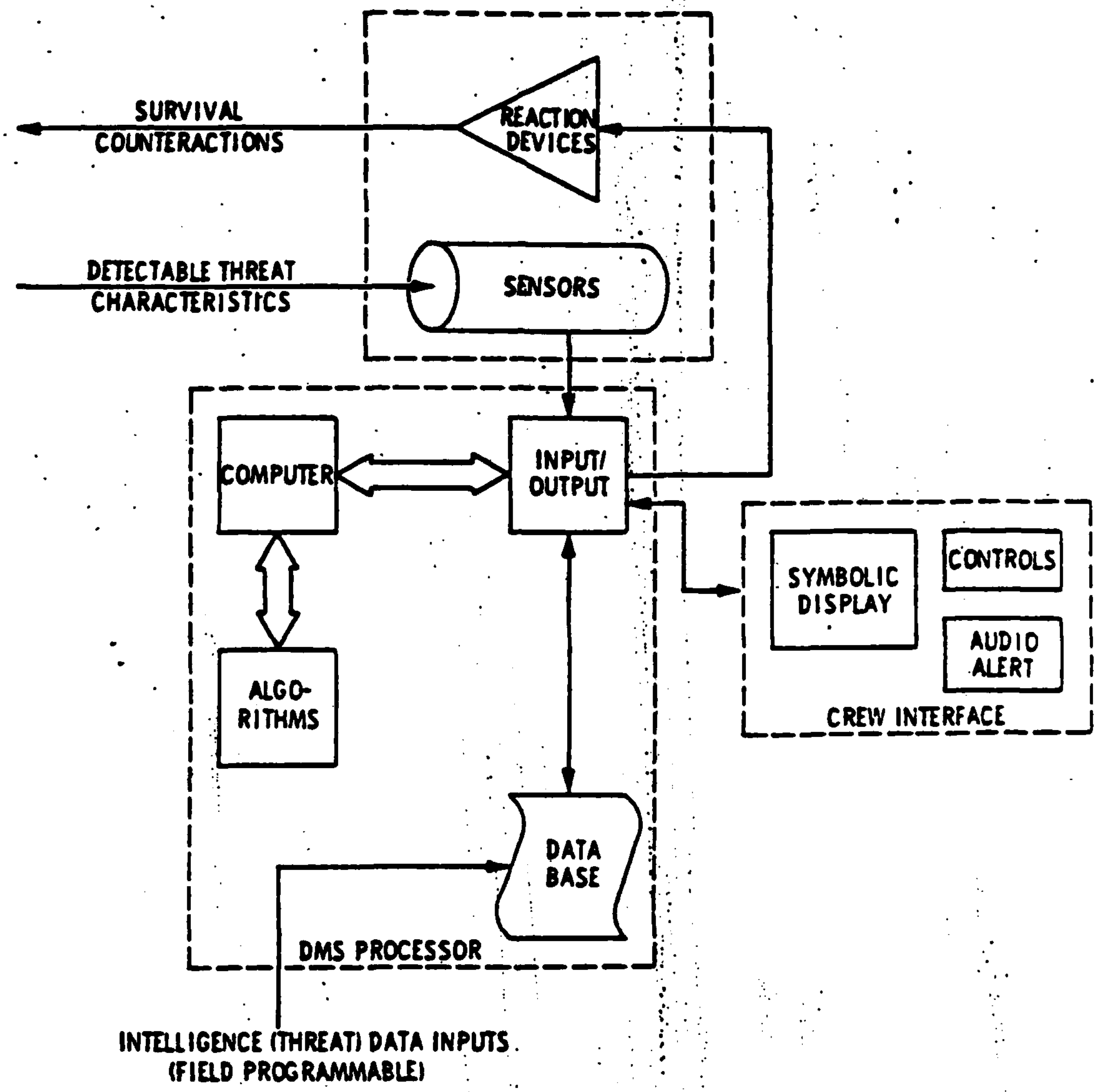

Figure 1. General Concept of the VIDS-DMS
(Reproduced from R-3710-10279, page 1-3.)

ANALYSIS AND GENERAL FINDINGS

Overview

Two primary sources provided data for the analysis of SMI issues in VIDS-DMS software modules and processes: VIDS-DMS developer personnel, and the draft Procurement Specification cited earlier. Interviews and study of the document revealed that the FDM's operational software will consist essentially of an executive and nine functional modules. As shown in Figure 2, six of these modules are divided into subordinate processes which serve specific purposes within the overall purpose of the parent module. Each module and/or process was analyzed for implications concerning the FDM's SMI, and recommendations to resolve SMI design issues were developed. The analysis procedure and general findings are discussed immediately below; individual modules and processes are discussed in the following section.

Procedure

For each module or process, analysis consisted of first preparing a flow chart. This chart does not attempt to represent the structure or operation of the module or process *per se*. Instead, it shows the module's or process's inputs and outputs, its relationship to other modules or processes, and points of interaction with the crew. Thus, flow charts presented in the next section are drawn at a relatively general level, which nonetheless is adequate to the needs of this project.

The next step in the analysis required preparation of a functional description of the module, based upon information extracted from the draft Procurement Specification, obtained from developer personnel at TACOM, or derived from the flow chart. The description serves two purposes:

1. It documents the contractor's understanding of system software functions.

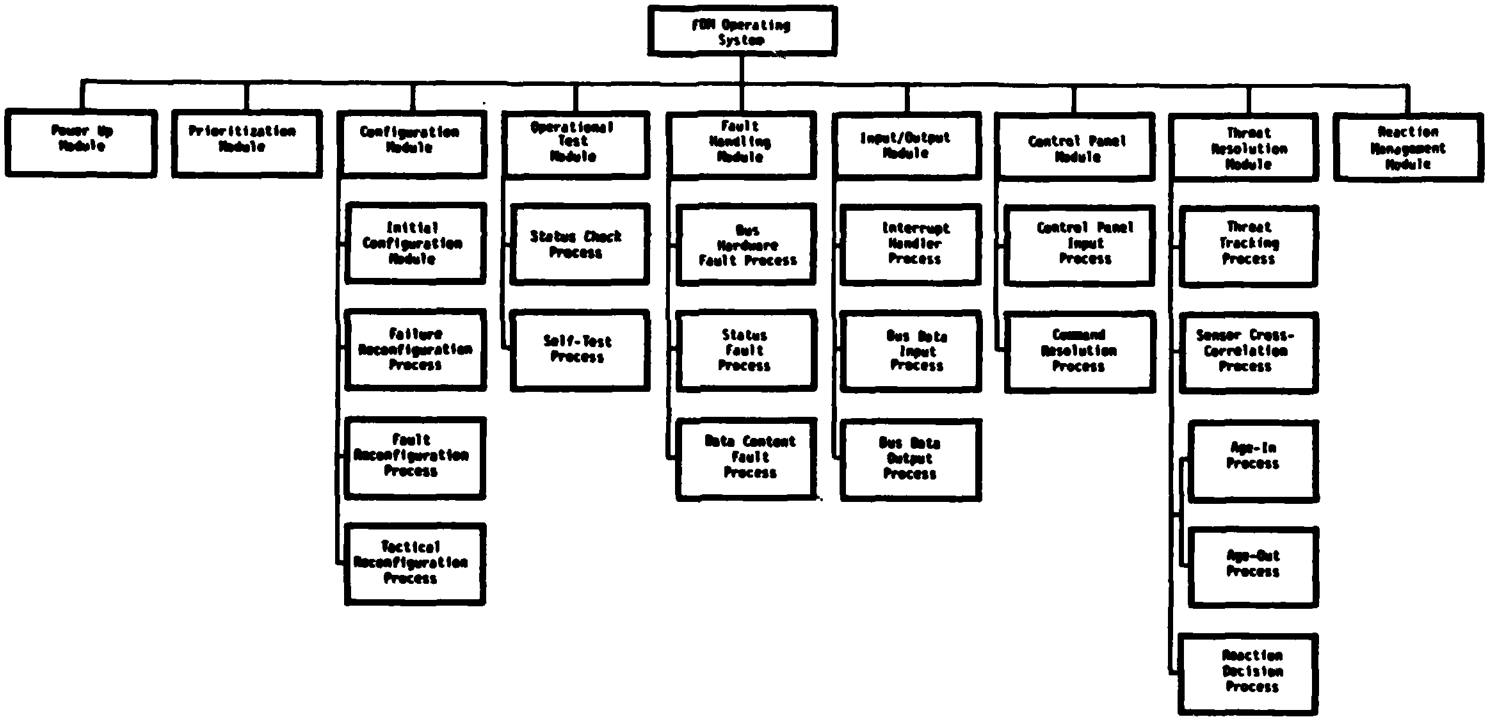

Figure 2. FDM-DMS Operations Software Family Tree
Main Process Modules
(Redrawn from R-3710-10279.)

2. It provides an overview of the module or process for the benefit of readers unfamiliar with the VIDS-DMS.

The analyst then described SMI implications of the module's or process's points of interaction with the crew. This discussion noted types of interactions likely to be required and, where possible, tasks likely to be imposed on the crew. Finally, the analyst developed recommendations to resolve selected issues implied by the analysis, and suggested sections of the Prototype Handbook containing guidance relevant to that issue.

Because of limited resources, the analysis normally ended with these suggestions. However, to provide more detailed examples of the use of the Handbook, in two cases the analysis was carried further. Application topics and interaction methods were discussed, drawing upon a specific guideline subsection. Then, the subsection's matrix of applications versus methods was reproduced, and the method appropriate to the specific VIDS-DMS application was pointed out. This extended discussion of guidelines was provided for the Failure Reconfiguration Process and for the Status Fault Check Process.

General Findings

VOLUME OF INTERACTION

In contrast with other systems analyzed during Synectics' earlier contract with ARI, the VIDS-DMS apparently will require minimal interaction with the crew. Sensor data will be transmitted automatically from peripheral devices to the DMS, where they will be processed and evaluated automatically, ordinarily without the need even for advice from the crew. Similarly, threats will be detected, located, classified, and prioritized, and recommended reactions will be developed without crew interaction. Thus, system communications with the crew typically will be conducted on an exception basis, as for example when a threat reaction must be approved or when a failed peripheral must be removed.

The decision to take this approach to system-crew interaction is probably wise. The VIDS-DMS will be installed on a platform whose movement over terrain will affect crew members' abilities to perform accurate physical actions such as pressing keys and pointing light pens. Combat will add confusion, noise, and high levels of stress. In this chaotic environment, crews will be required to make sound decisions rapidly, choosing from a limited number of fixed alternatives often based on incomplete or uncertain information. Given these conditions, they must not be required to master and use complex command languages, extensive interactive procedures, or other sophisticated computer skills in the bargain.

There is another important reason to adopt a "minimalist" approach to SMI design for the VIDS-DMS. The system offers great potential for enhancing vehicle and crew survival, but to provide that enhancement it exacts a price: the system will add tasks to the workload of at least one vehicle crew member. These tasks must be integrated very carefully into the current duties of the affected crew jobs. Otherwise, performing VIDS-DMS tasks may conflict with other tasks, or overburden one or more crew members. The consequences of such an outcome--degraded crew performance--might well defeat the very purpose the VIDS-DMS was designed to serve.

DESIGN OF TRANSACTIONS

Reduced levels of interaction in the VIDS-DMS as compared with many other battlefield automated systems does not reduce the requirement for care in the development of its SMI. Tasks must be structured to ensure that, while accomplishing the system's purposes, they are reduced to the minimum number absolutely required. Performance of these tasks must not interfere with or detract from the timely, accurate performance of other important crew activities. Furthermore, the design of these tasks must be as simple and straightforward as possible, to avoid imposing unnecessary additional skill requirements on the crew. Also, equipment and transaction procedures must be designed to ensure that tasks that have been carefully developed in accordance with these principles will not be disrupted by inconsistent, inappropriate, or inconvenient SMI design features.

Information to be presented on displays must be selected in accordance with rigid criteria of relevance and need, so that all essential information--but only essential information--reaches the crew. Of course, individual information elements must also reach the crew at the times they are needed.

Moreover, presentation formats must be designed to present that information logically, in the sequence that it will be used, and in arrangements on the display that facilitate rapid, accurate interpretation and understanding. At the same time, input methods for command and data entry must be kept as simple as possible, and be designed for fast, easy entry while keeping opportunities for crew members to commit errors to the minimum.

In this project, issues such as these could not be explored as thoroughly or in the depth that they clearly require. Certainly, they should be given careful and continuous attention throughout VIDS-DMS development, beginning as early as possible. Meanwhile, the following section provides an initial analysis of specific SMI issues in the system's modules and processes, and suggests resolutions for some of these issues. This document therefore may serve as a starting point for the more extensive effort that must be performed.

MODULES AND PROCESSES

Power Up Module and Initial Configuration Process

Description

The Power Up Module and the Initial Configuration Process, illustrated in Figure 3, are discussed jointly here, for two reasons:

1. They apparently never operate independently; the Initial Configuration Process is not invoked unless the Power Up Module has been invoked first.

2. The Power Up Module and Initial Configuration Process are both invoked in only one situation: when power is first applied to the system.

The VIDS-DMS employs a typical "cold start" procedure. That is, the Power Up Module is called by a hardware interrupt that is generated automatically when the system initially receives electrical power. The Power Up Module reads in all the system's program and data files and then requests the Configuration Module, which in turn invokes the Initial Configuration Process.

The Initial Configuration Process uses data from the Initial Configuration Selection Tables and from the Peripheral Status and Vehicle Data Files to set up the system's operational configuration of sensors, reaction devices, and data processing capabilities. It stores the appropriate data in the Configuration Status File for use by other modules and processes, and then generates an output to the Control Panel Output File.

Soldier-Machine Interface Implications

The only requirement for the Power Up Module appears to be an "ON/OFF" switch (the simplest type of crew "input") and some form of positive feedback, such as an indicator light above the switch or a light behind the switch itself.

The Initial Configuration Process's concluding output to the Control Panel Output File clearly contains a message to the crew. The draft Procurement Specification does not describe this message; presumably it notifies the crew that the system is ready for use.

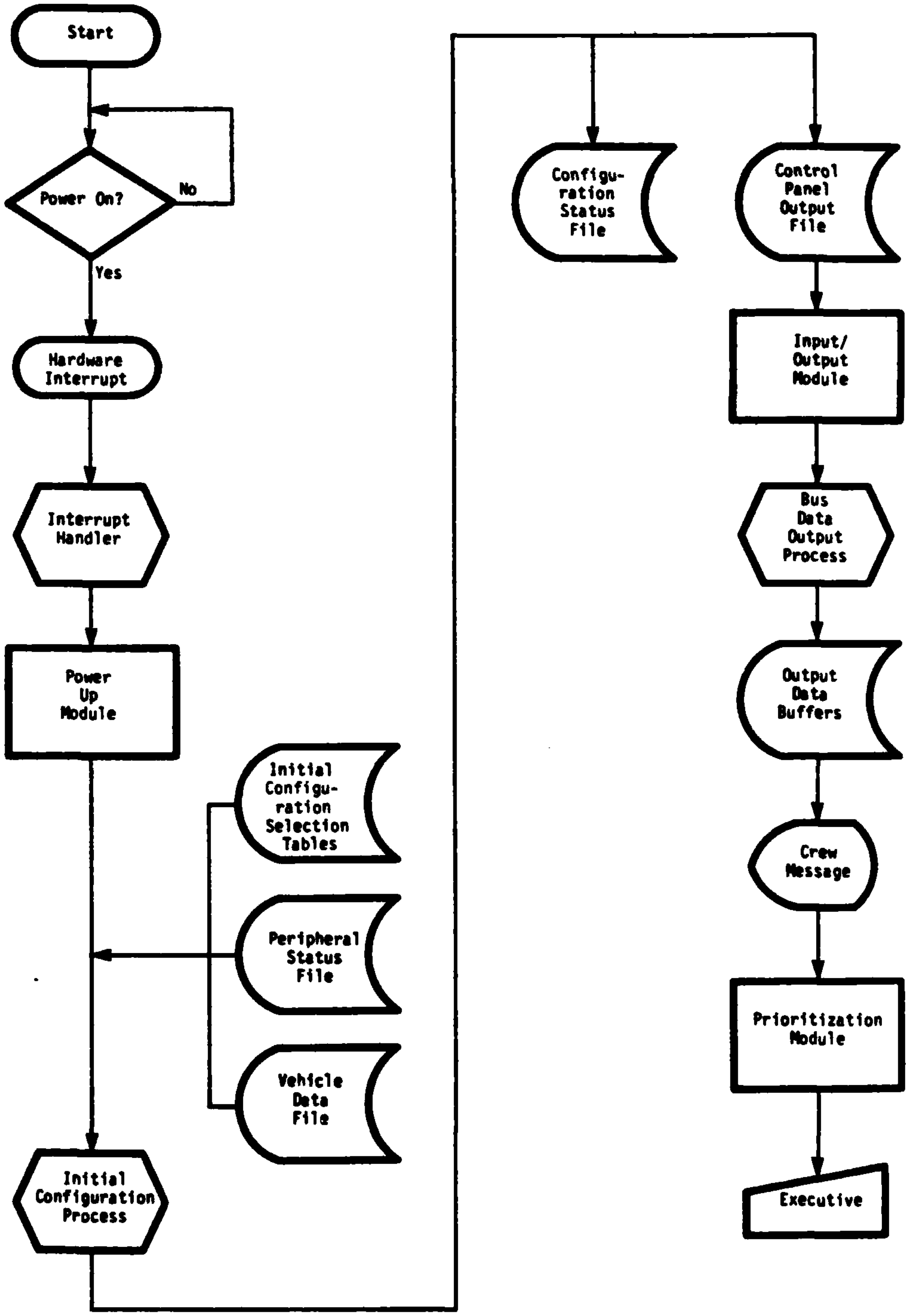

Figure 3. Schematic of System Functions Involving the Power Up Module and the Init al Configuration Process in the Configuration Module

Apparently, the VIDS-DMS will not provide any capability for performing a "warm start." That is, in the procedure described above, the Power Up Module loads program files and all relatively permanent data stored in the system, such as threat priorities, aging parameters, and vehicle characteristics. However, there is no indication in the draft Procurement Specification that ephemeral data such as sensor cross-correlations, threat locations, current peripheral status, or pending crew commands can be saved during system shut-down procedures.

And yet, one can imagine situations in which a vehicle crew might want to preserve these data for a short period while the system is temporarily inoperative. For example, during a lull in the battle, the crew might be relatively secure from danger even though enemy forces are within range of at least some VIDS-DMS sensors. After assessing the situation, the vehicle commander might accept a relatively low risk in order to shut down the vehicle and perform an urgent but quickly-accomplished repair. Such repair might involve the VIDS-DMS or some other vehicle system which requires complete removal of vehicle power. Upon restoring power in this situation, the crew very well might want the system to pick up precisely where it left off, with all ephemeral data intact and available for subsequent system operations.

Recommendations

1. Provide information in the Initial Configuration Process message to notify the crew of the status of system peripherals. This message should be brief (e.g., "READY. NO EQUIPMENT PROBLEMS" or "READY. OPTICAL SENSOR INOP."). (NOTE: Examples such as these are not intended to be recommended specifications; they merely exemplify the types of transactions being discussed.) A graphic presentation could be used (e.g., an outline of the vehicle with green spots at the locations of operating peripherals and red at the locations of inoperative peripherals); however, a simple alphanumeric message would probably be understood more quickly. Guidelines relevant to this issue are presented in the following sections of the Prototype Handbook:

   2.1 Alphanumeric Displays

   2.3 Selective Highlighting

   6.2 Standard Terms

2. Explore the necessity for a "warm start" capability. If the capability is justified, then a power shut down procedure will be required that gives the crew the option to discard ephemeral data (for a later cold start) or to save it (for a later warm start) before power is actually removed. When the "ON/OFF" switch is turned to the "OFF" position, a simple query should be addressed to the crew regarding their wish to discard or preserve the ephemeral data. Relevant guidelines will be found in the following sections of the Prototype Handbook:

   1.1 Alphanumeric Control Methods

   2.1 Alphanumeric Displays

   6.2 Standard Terms

Prioritization Module

Description

The Prioritization Module, shown schematically in Figure 4, is responsible for prioritizing and scheduling the VIDS-DMS main processing modules. This will include the Configuration, Operational Test, Fault Handling, Input/Output, Control Panel, Threat Resolution, and Reaction Management Modules. The Prioritization Module responds whenever any process is either completed or suspended. The module directly interfaces with the Configuration, Fault Handling, and Control Panel Modules through the Process Request List. The Threat Resolution Module is interfaced through the Prioritized Threat List and the Reaction Management Module through the Reaction Data File. Files that support the Prioritization Module include Peripheral Status and Vehicle Data Files. Both these files are updated by the Configuration, Operational Test, and Fault Handling Modules. The Prioritization Module also interfaces the Executive through the Process Schedule and is real-time critical. The Prioritization Module performs the prioritization, scheduling, and configuration control functions at the highest level of responsibility not performed by the operating system. The Prioritization Module is additionally supported by the Prioritized Threat List, Process Prioritization Tables, Process Request List, Reaction Data Files. (NOTE: All processes/modules output to the Process Request List for use by the Prioritization Module and, ultimately, Process Scheduling.)

Soldier-Machine Interface Implications

The actions of the Prioritization Module are transparent to the crew. While a process initiated by the Prioritization Module may eventually interface the crew, the Prioritization Module itself does not. The Prioritization Module in and of itself does not affect the SMI.

Recommendations

As the Prioritization Module does not directly impact the SMI, no interface recommendations are applicable.

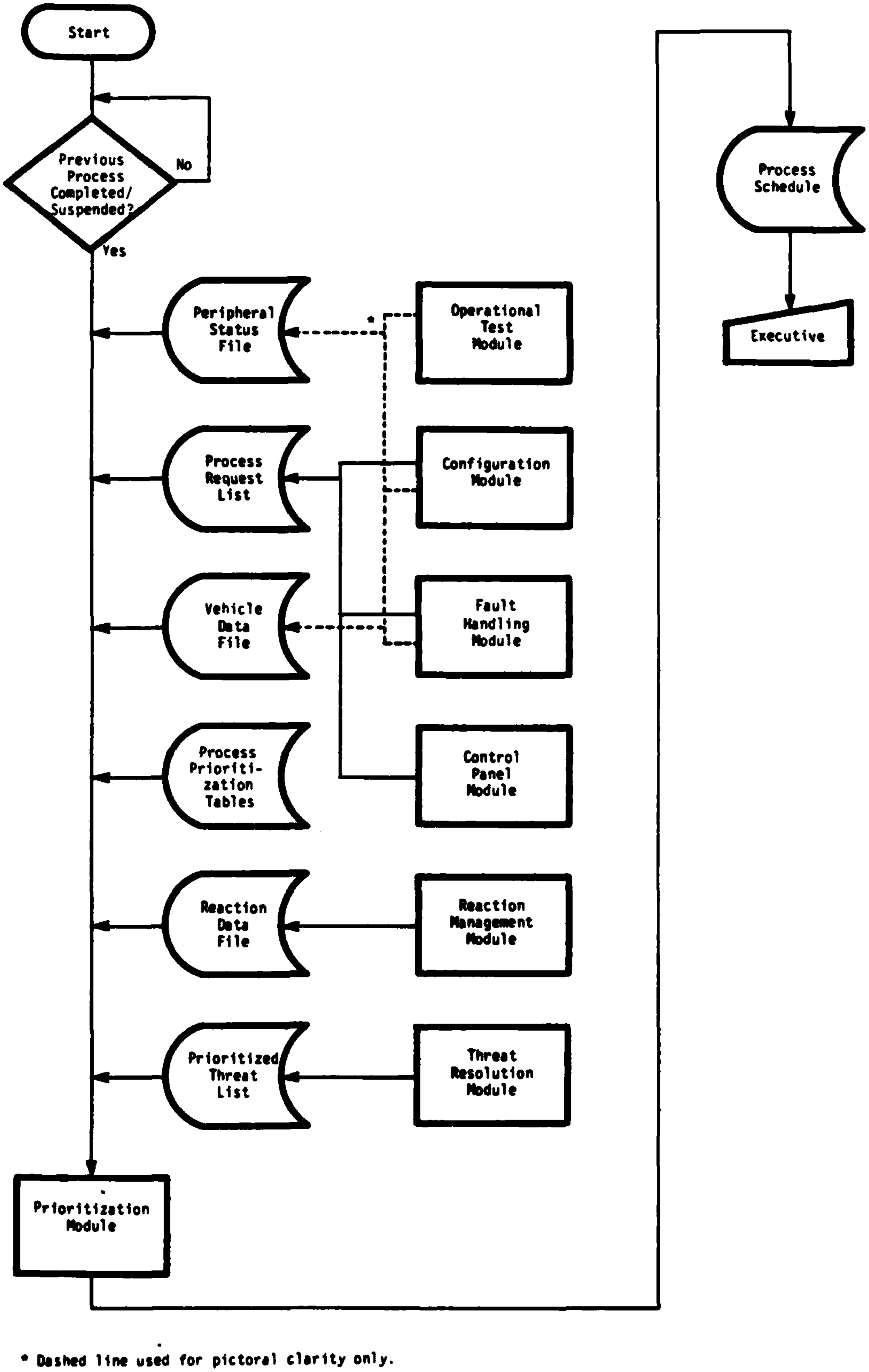

Figure 4. Schematic of System Functions Involving the Prioritization Module

Configuration Module

The Configuration Module is responsible for the configuration of the DMS. Its overall effect is the ordering and reordering of software processing in response to a peripheral failure, a peripheral fault, or a change in the tactical situation. Four processes constitute the Configuration Module: the Initial Configuration Process, the Failure Reconfiguration Process, the Fault Reconfiguration Process, and the Tactical Reconfiguration Process. (NOTE: The Initial Configuration Process was discussed previously, in conjunction with the Power Up Module.)

FAILURE RECONFIGURATION PROCESS

Description

The information flow and sequence for the Failure Reconfiguration Process are illustrated in Figure 5. The essential purpose of the process is to reconfigure system tables, parameters and program modules in response to a peripheral or bus failure. The Failure Reconfiguration Process is requested by the Fault Handling Module after a hardware interrupt. The process is supported by the Fault Handling Module, the Peripheral Status File, the Vehicle Data File and the Failure Reconfiguration Selection Tables. Upon process completion, the Failure Reconfiguration Process updates the Configuration Status File to incorporate the new configuration, and interfaces directly with the Input/Output Module through the updated Control Panel Output File. The Failure Reconfiguration Process works in coordination with the Initial Configuration Process, Fault Recovery Process, and the Tactical Reconfiguration Process.

Soldier-Machine Interface Implications

The Failure Reconfiguration Process's direct interface with the Input/Output Module through the Control Panel Output File suggests that the process generates a message to the crew. However, the Draft Specification does not specify the purpose or content of any such message. The document does state that the Status Fault Process and/or the Data Content Fault Process will generate the appropriate message whenever a failed peripheral

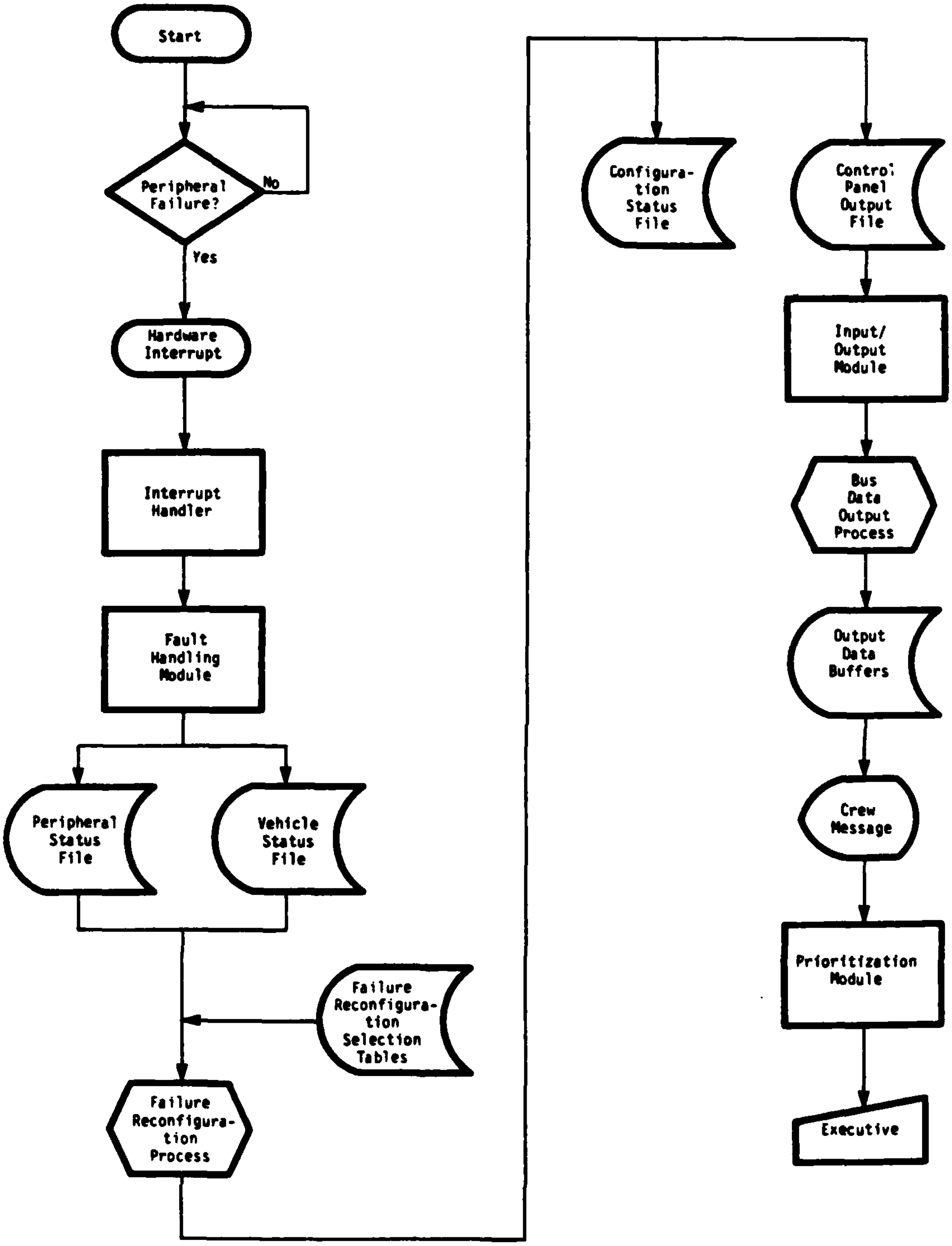

Figure 5. Schematic of System Functions Involving the Failure Reconfiguration Process in the Configuration Module

must be physically removed. Therefore, one may infer that the message generated by the Failure Reconfiguration Process serves some other function than peripheral removal. That function appears to be to notify the crew that reconfiguration has taken place. If so, the question arises as to the importance of this notice as compared to other information (for example, warnings of imminent threats). Also, the method of presenting the message becomes an issue.

The Draft Specification appears to allow no capability for the crew to overrule the Failure Reconfiguration Process. Presumably, the Process reconfigures the system based upon information stored in the Peripheral Status File by other processes. The cause of a failure notification in that file evidently results from a comparison of peripheral status against some minimum acceptable value. However, one can conceive of situations in which that value is lower for the crew than for the system. That is, under the exigencies of combat, the crew might prefer the assistance of even a seriously degraded (but not completely failed) peripheral, given the alternative of no peripheral at all. Probably, disucssion with subject matter experts would resolve this issue.

Recommendations

1. The crew should be notified immediately of any reconfiguration unless more pressing information (e.g., a threat warning) is available. This notification should be presented as an alphanumeric text message indicating the identification of the peripheral that has been configured out of the system and the reason for the reconfiguration (e.g., the peripheral is inoperative, voltage has dropped below its minimum acceptable value). The peripheral identification should be highlighted to permit easy detection by the crew of this critical piece of information. The notification should be maintained on the display device until acknowledged by the crew.

   Sections of the Prototype Handbook relating to display issues in the Failure Reconfiguration Process are:

   2.1 Alphanumeric Displays

   2.3 Selective Highlighting

   3.2 Unburdening of Input

   6.1 Symbols and Symbol Sets

6.2 Standard Terms

6.3 Abbreviations

7.1 Error Feedback

7.2 Error Correction and Recovery

2. Additionally, if TACOM determines that the crew requires the capability to overrule this process, then crew instructions to the process should be entered using simple alphanumeric control methods. Relevant guidance is provided by the Prototype Handbook in:

    1.1 Alphanumeric Control Methods

    3.1 Information on Legal Entries

Example of Handbook Usage. For an example of the use of guidelines, consider the message that reconfiguration has been accomplished. The crew needs to know which peripheral has failed and caused the failure reconfiguration, because this information may well influence decisions for the remainder of the mission. Therefore, as noted above, this critical item of information should be highlighted to help the crew locate the information quickly. Section 2.3 of the Prototype Handbook describes and illustrates various applications for selective highlighting, and various highlighting methods.

One application described in this section is "to call attention to high priority codes or messages" (such as a failed peripheral). The Handbook provides the following example of this application:

> EXAMPLE: In an artillery data system, the user/operator must be certain that the target coordinates for a fire mission do not mean that friendly fire will impact on friendly forces. The data indicating these coordinates is therefore highlighted when it is displayed (page 2.3-3).

In describing methods for highlighting, the Handbook mentions brightness control as one such method:

Brightness control. The information which is highlighted appears brighter than other information on the display.

```
NO MATCH ON FILE NAME "CHKSUM"

DO YOU WISH TO:

     1.  ENTER A NEW RETRIEVAL NAME

     2.  REVIEW THE VALID FILE NAMES

     3.  PERFORM ANOTHER OPERATION




-->
```

(NOTE: In the example, the words "ENTER," "REVIEW," and "PERFORM" are represented in the display as brighter than other words.)

Table 1 (reproduced from Table 2.3-3 in the Handbook, page 2.3-13) presents recommendations concerning preferred highlighting methods for different applications. The table shows that for high priority messages or codes, four methods are recommended: brightness control, character size control, color control, and boxing. For purposes of standardizing soldier-machine interactions in Army battlefield automated systems, the table recommends using brightness control, and that method is therefore recommended for the VIDS-DMS.

Table 1. Method of Selective Highlighting by Reason for Using Highlighting

KEY:

1 - RECOMMENDED

2 - ACCEPTABLE

3 - WORKABLE BUT SUBOPTIMAL

4 - NOT RECOMMENDED OR NOT APPLICABLE

METHOD	APPLICATION: Unusual Values	Information Changed	Information to be Changed	High-Priority Messages/Codes	Alarms	Special Areas of Display	Command/Data Entry Errors	Warnings of Consequences	Indicate Search Targets
Brightness Control	1*	1*	1*	1*	2	1*	1*	1*	1*
Character Size Control	1	1	1	1	4	4	1	1	2
All Upper Case	2	2	2	2	3	4	2	2	4
Reverse Display	2	2	2	2	2	3	2	2	1
Underlining	2	2	2	2	3	3	2	2	4
Different Font	2	2	2	2	3	4	2	2	4
Color Control	1	1	1	1	2	1	1	1	1
Blinking, Pulsating	3	3	3	2	1*	3	4	3	2
Boxing	3	3	3	1	4	1	1	2	2
Arrowing	2	2	2	3	4	4	4	2	2
Symbolic Tagging	2	2	2	4	4	3	4	4	2
Alphanumeric Tagging	4	4	4	4	3	3	3	4	3
Position Displacement	2	2	3	3	3	4	4	2	2

* Recommended as 1st choice for standardization purposes.

FAULT RECONFIGURATION PROCESS

Description

The Fault Reconfiguration Process, shown schematically in Figure 6, is responsible for the reconfiguration of the DMS in the event of a fault condition. This differs from the Tactical Reconfiguration Process which reconfigures from a change in a tactical situation. The Fault Reconfiguration Process is called by the Fault Handling Module through the Peripheral Status File and Vehicle Data File interfaces. The Vehicle Data File and Peripheral Data File support the Fault Reconfiguration Process as do the Fault Reconfiguration Selection Tables and the Process Schedule. The Fault Reconfiguration Process interfaces the Executive through the Process Schedule and the Input/Output Module through the Control Panel Output File. The process also updates the Configuration Status File for use by other system modules. This process is real-time critical and generates a message to the Control Panel Output File.

Soldier-Machine Interface Implications

The Fault Reconfiguration Process is anticipated to generate a status or warning message to the crew. The message may be aural, or involve the display, or both. The crew may be expected to acknowledge the message through a simple mechanism such as a push-button. The details of the SMI implication are the same as those expressed for the Failure Reconfiguration Process and are not duplicated here.

Recommendations

Recommendations 1 and 2 of the Failure Reconfiguration Process apply.

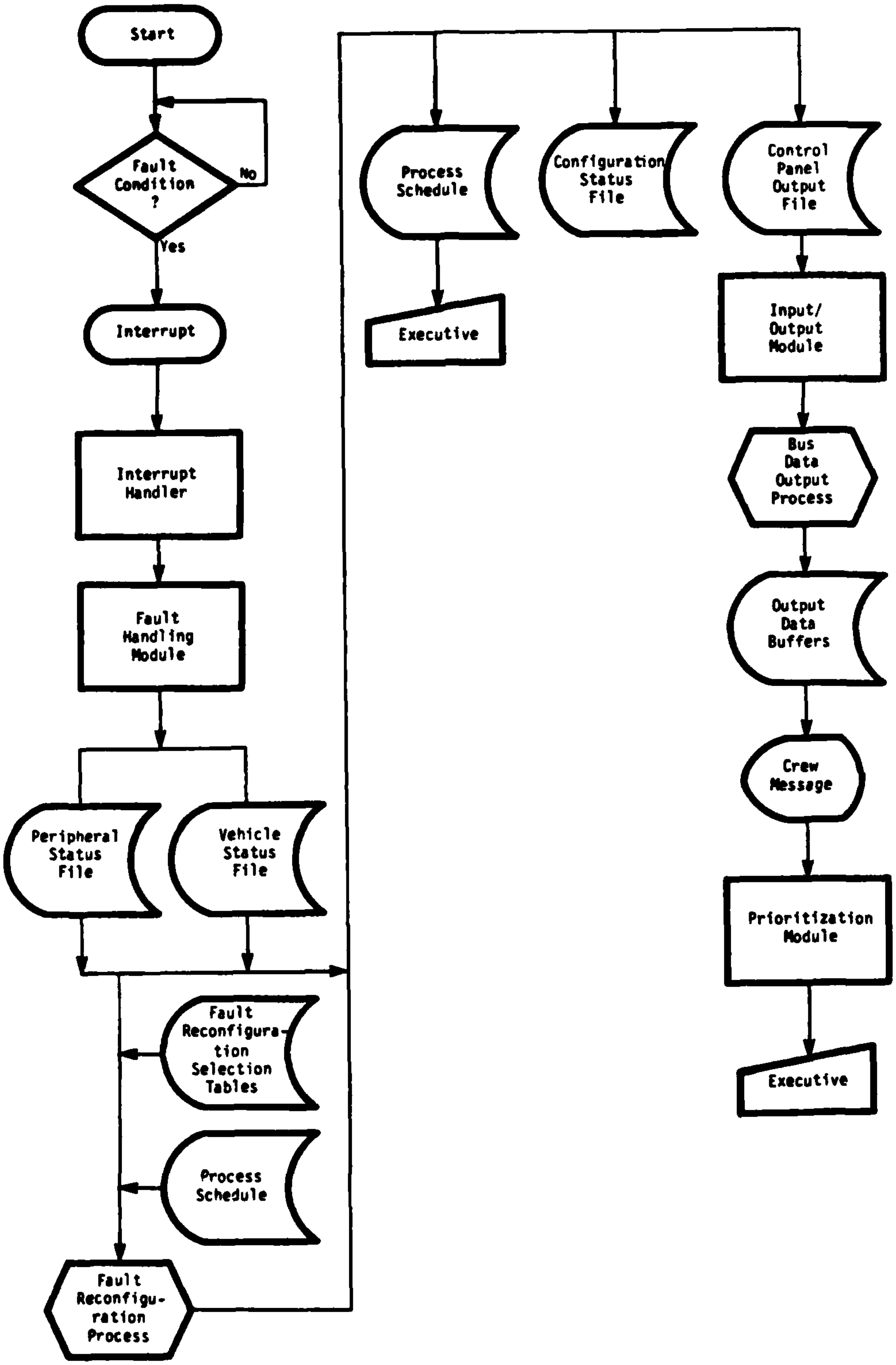

Figure 6. Schematic of System Functions Involving the Fault Reconfiguration Process in the Configuration Module

TACTICAL RECONFIGURATION PROCESS

Description

The Tactical Reconfiguration Process, shown schematically in Figure 7, performs the function of reconfiguring tactical processing in response to a change in the vehicle's tactical situation. The Tactical Reconfiguration Process is requested by the Prioritization Module or by crew input. The process is supported by the Tactical Reconfiguration Selection Tables and updates, as an output, the Configuration Status File and the Peripheral Command File. The Peripheral Status File and the Vehicle Data File are also updated and used by the Prioritization and Threat Resolution Modules. The updated Configuration Status File is available for system-wide modules. The Process Schedule is also modified by the Tactical Reconfiguration Process for changes in the processing sequence. The updated Peripheral Command File is used for changes in the Self-Test and Status Check Processes.

Soldier-Machine Interface Implications

The draft Procurement Specification does not show any output to the Control Panel Output File from the Tactical Reconfiguration Process. However, if tactical reconfiguration results in any pronounced change in the system's configuration, then a message to the crew announcing this change should be provided. Such a message would be important to confirm a reconfiguration initiated by crew input; it will be particularly important when a tactical reconfiguration has been initiated automatically by the system.

In the case of crew input initiating a tactical reconfiguration, that input presumably would be entered as a crew response to a perceived change in the tactical situation during combat operations. The draft Procurement Specification does not describe the extent of crew control when they invoke the Tactical Reconfiguration Process. For example, would the crew input consist merely of a command to execute the process, at which command the system would take over and reconfigure without further crew participation? Or would the crew play a more active role in the process, perhaps having the capability to specify desired reconfiguration parameters? In the latter case, then the method for presenting these parameters as input options must be clear

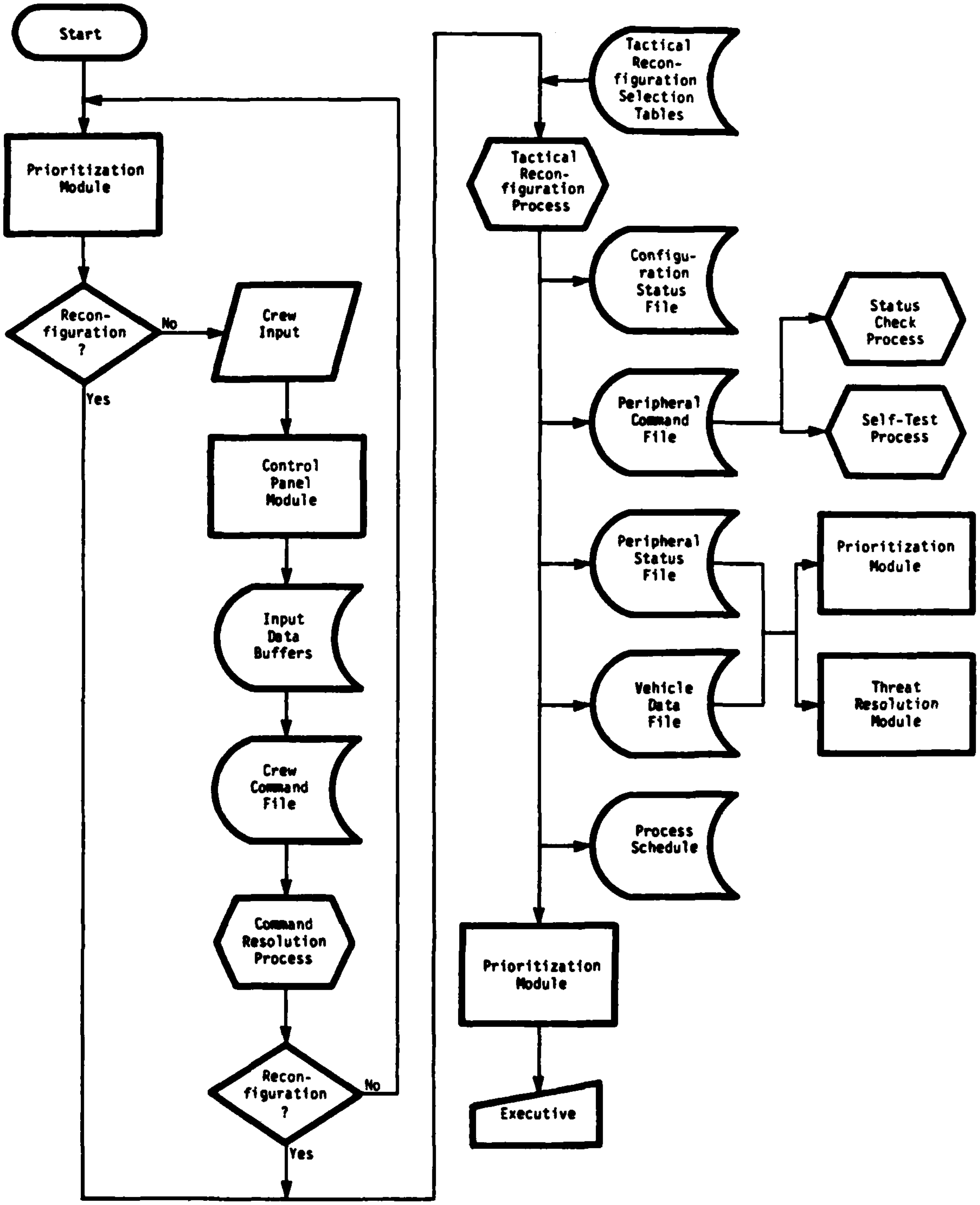

Figure 7. Schematic of System Functions Involving the Tactical Reconfiguration Process in the Configuration Module

and unequivocable; the demand for crew consideration and decision making must be minimized. Similarly, the method for entering parameter selections must be simple and rapid, with minimal demand for physical skills. Because tactical reconfiguration usually will be performed under battlefield conditions where seconds literally may be crucial to vehicle and crew survival, considerations of speed and simplicity must be paramount in the design of the crew-system interaction.

Recommendations

The following recommendations assume that crew input to the Tactical Reconfiguration Process consists of something more than a simple initiating command.

1. Provide a method to make reconfiguration options available to the crew on the alphanumeric display. Give the crew the capability to enter peripheral device selections by number. Do not require reference to offline documents or other crew members for this procedure; provide all required information through the system. Guidelines relevant to this recommendation include the following sections in the Prototype Handbook:

   1.1 Alphanumeric Control Methods

   2.1 Alphanumeric Displays

   2.2 Graphics Displays

   3.1 Information on Legal Entries

   3.2 Unburdening of Input

   6.1 Symbols and Symbol Sets

   6.2 Standard Terms

   6.3 Abbreviations and Codes

   7.1 Error Feedback

   7.2 Error Correction and Recovery

2. The selection of peripheral devices must be accomplished by no more than one action (e.g., keystroke) per device.

3. The inadvertant selection of a failed or unavailable peripheral must invoke a system-generated message to this effect. This message should require a positive corrective

action by the crew, to avoid the possibility they will conduct subsequent operations based on an erroneous belief that a failed or otherwise unavailable peripheral is operating normally.

The following recommendation deals with the need for an output message to the crew following tactical reconfiguration, and is not related to the nature of crew-system interaction in initiating the process.

4. Provide a message to the crew showing the new configuration after tactical reconfiguration has been accomplished. Guidelines appropriate to this recommendation are suggested under "Recommendations" for the Failure Reconfiguration Process.

Operational Test Module

The Operational Test Module provides the system with a built-in test capability. It is comprised of the Status Check Process and the Self-Test Process.

STATUS CHECK PROCESS

Description

The Status Check Process, shown schematiclaly in Figure 8, performs routine monitoring of the operational status of all peripheral components. If a peripheral failure is detected, the Input/Output Module invokes the Status Check Process through the Status Input Buffer. Using data from the Configuration Status File, the Status Check Process checks the status of peripherals through the Input/Output Module (via the Peripheral Command File) and modifies the Peripheral Status File and the Vehicle Data File for use by the Configuration Module, the Prioritization Module, and the Threat Resolution Module. It also outputs the results of the status checks to the Process Request List for use by the Prioritization Module. The process monitors normal operation; it does not perform fault diagnosis or test peripheral component operation. The effect of the Status Check Process is merely to announce a peripheral failure, calling to the attention of the Prioritization Module the need to schedule failure diagnosis/correction by other processes.

Soldier-Machine Interface Implications

The Status Check Process itself provides no message to the crew regarding the status of peripheral component operation nor does it directly occasion any soldier-machine interaction.

Recommendations

Because the Status Check Process does not interact with the crew, no recommendations are required.

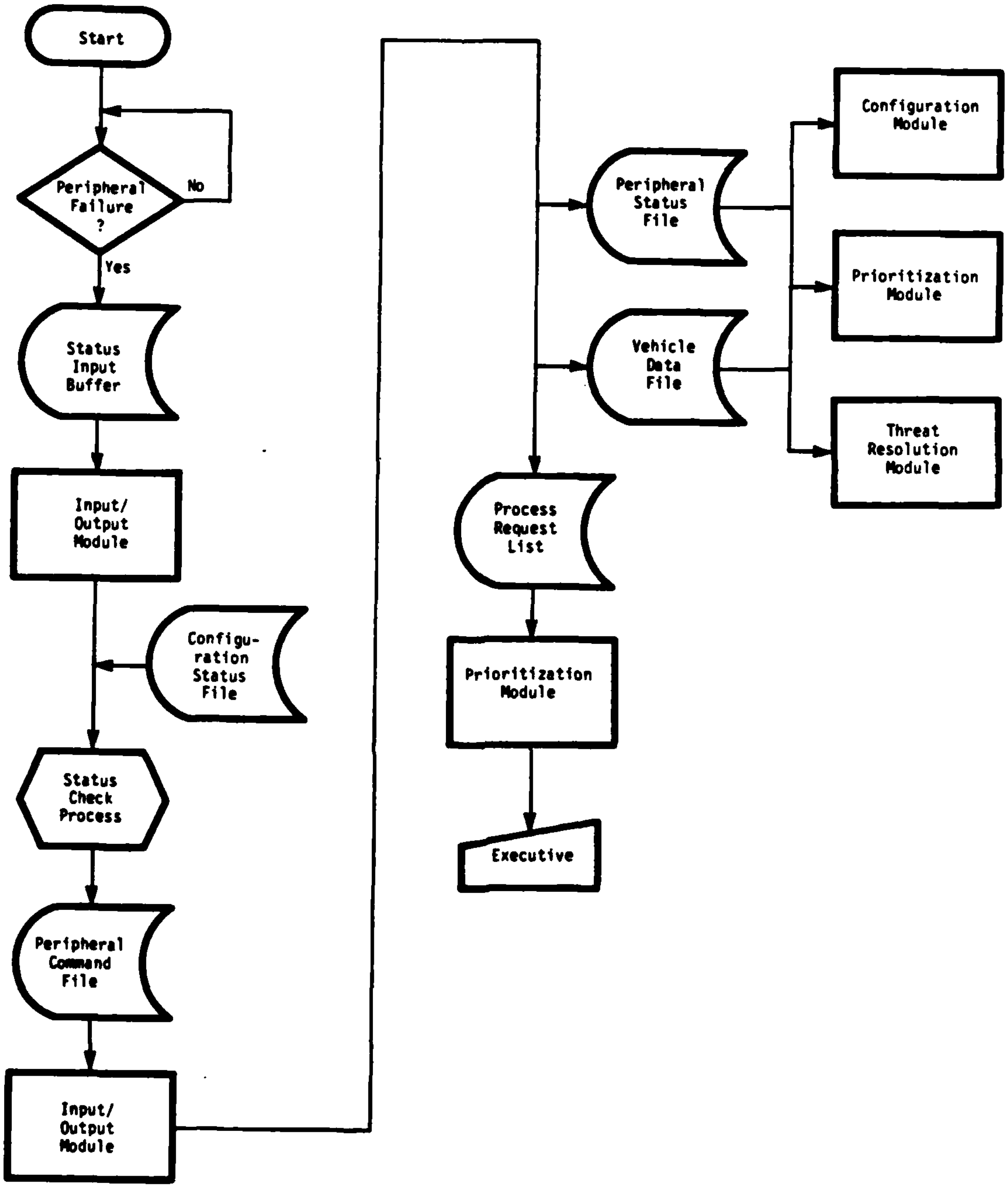

Figure 8. Schematic of System Functions Involving the Status Check Process in the Operational Test Module

SELF-TEST PROCESS

Description

The Self-Test Process, illustrated schematically in Figure 9, handles unscheduled or infrequently scheduled system diagnostics. Interpretation of the draft Procurement Specification suggests that the Self-Test Process does not itself perform these diagnostic functions. Instead, it calls the process or processes which do the actual diagnostic testing on the questionable peripheral.

The Self-Test Process is requested by the Fault Handling Module, when more thorough testing than that performed by the Status Check Process is desired. The Fault Handling Module may be called in response to automatic system procedures or in response to a crew input; in either case it calls the Self-Test Process to handle the more extensive testing. The process uses data from the Configuration Status file and from the Test Selection Tables. Based upon fault indicator parameters in the Configuration Status File, the Test Selection Tables point to the particular self-test process (procedure) that is appropriate to the specific diagnostic situation.

The Self-Test Process generates commands to peripherals, which it stores in the Peripheral Command File. The Input/Output Module interprets these commands and modifies the Peripheral Status File and the Vehicle Data File for subsequent use by the Configuration Module, the Prioritization Module, and the Threat Resolution Module.

Soldier-Machine Interface Implications

As noted above, the Self-Test Process is invoked only when more thorough testing is required than is normally performed by the other diagnostic processes that are called automatically in response to system interrupts. Presumably then, the crew will call for this process only when they have reason to suspect that one of the system's peripherals is not operating normally. Such suspicions might be aroused either by system reports of other test results, or by direct crew observations of the peripheral's performance. In either case, the Self-Test Process will not be a routine, frequently used procedure.

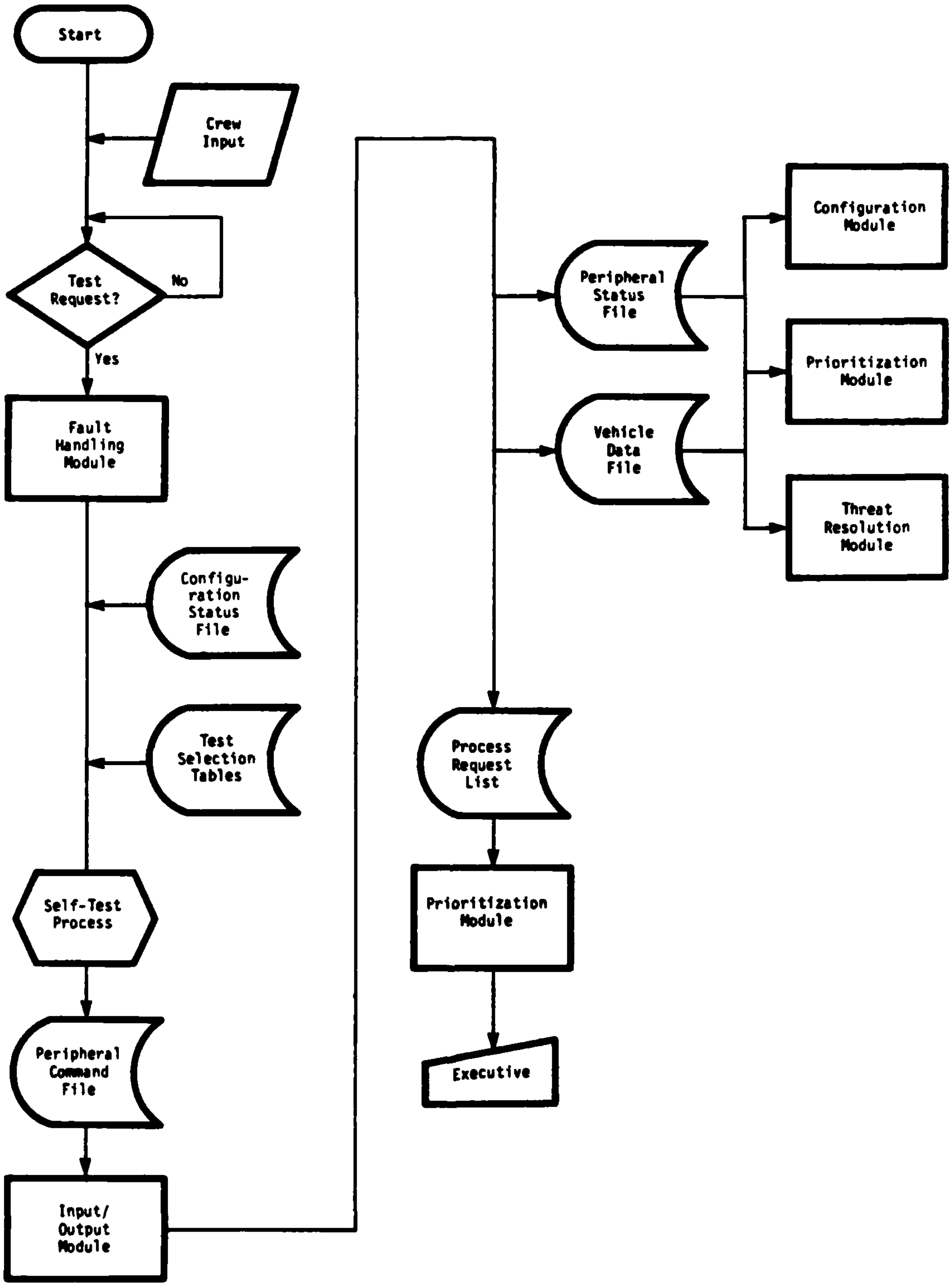

Figure 9. Schematic of System Functions Involving the Self-Test Process in the Operational Test Module

The crew naturally will have received instruction and practice in its use as part of their training. However, precisely because they will use it relatively rarely during combat operations and/or exercises, they cannot be expected to learn it as thoroughly as other modules and processes. This fact must be an important consideration during the design of the SMI.

In addition, the draft Procurement Specification does not describe any kind of acknowledgement of a crew request for the Self-Test Process. Neither does it describe a message confirming that the process has been executed, or any kind of output to inform the crew of the system's conclusions regarding test results. The lack of acknowledgement, confirmation, and test conclusions would leave the crew in a state of pronounced uncertainty as regards system status, possibly at a time when critical decisions might hinge on such knowledge.

Recommendations

1. Provide an acknowledgement on the crew display whenever the crew calls for the Self-Test Process. This acknowledgement could be quite simple, for example "(name of peripheral) NOW BEING TESTED."

2. Whether invoked automaticlaly or by crew input, provide a message clearly stating the outcome of the Self-Test Process, informing the crew of any changes in peripheral status. If the Self-Test Process was called automatically, then provide this message only by exception, when status has actually changed. If the process was called by crew input, provide the message even if peripheral status has not changed.

3. Because of the relative infrequency of crew-system interaction relating to this process, exercise particular care in designing messages to the crew and structuring crew inputs. Provide ample explanation and instruction on performing the interaction, but avoid redundancy, repetition, and extraneous information. A naive operator should be able to complete the necessary transactions quickly, accurately, and without reference to off-line sources.

Guidelines relevant to support of interface issues of the Self-Test Process include:

1.1 Alphanumeric Control Methods

1.3 HELPs

2.1 Alphanumeric Displays

2.3 Selective Highlighting

3.1 Information on Legal Entries

3.2 Unburdening of Input

6.1 Symbols and Symbol Sets

6.2 Standard Terms

7.1 Error Feedback

7.2 Error Correction and Recovery

Fault Handling Module

The Fault Handling Module responds to fault conditions detected through normal operation or self testing. It consists of three processes with each process responding to a unique fault type: the Bus Hardware Fault Process, the Status Fault Process, and the Data Content Fault Process.

BUS HARDWARE FAULT PROCESS

Description

The Bus Hardware Fault Process is illustrated in Figure 10. The Bus Hardware Fault Process is called in response to a detected fault. The detected fault can be in the bus hardware, peripheral processor, or communication bus. The Fault Process is supported by the Configuration Status File and the Hard Fault Test Tables. The Bus Hardware Fault Process updates the Peripheral Status File and the Vehicle Status File. These files are used by the Configuration Prioritization and Threat Resolution Modules. The process also interfaces the Prioritization Module through the Process Request List. This process is considered real-time critical. The Bus Hardware Fault Process works in concert with the Status Fault Process and the Data Content Fault Process, both part of the Fault Handling Module.

Soldier-Machine Interface Implications

This process does not remove, shut down, or reconfigure devices, or initiate displays as part of its operation. Fault information appears to be used to update files for further processing by other modules. The process, therefore, appears to be transparent to the vehicle crew, although another module may use the fault information in such a manner as to affect the current configuration to necessitate status information or reaction by the crew.

Recommendations

As the Bus Hardware Fault Process does not appear to affect vehicle or crew performance as a direct result of its function, SMI guidelines are not indicated.

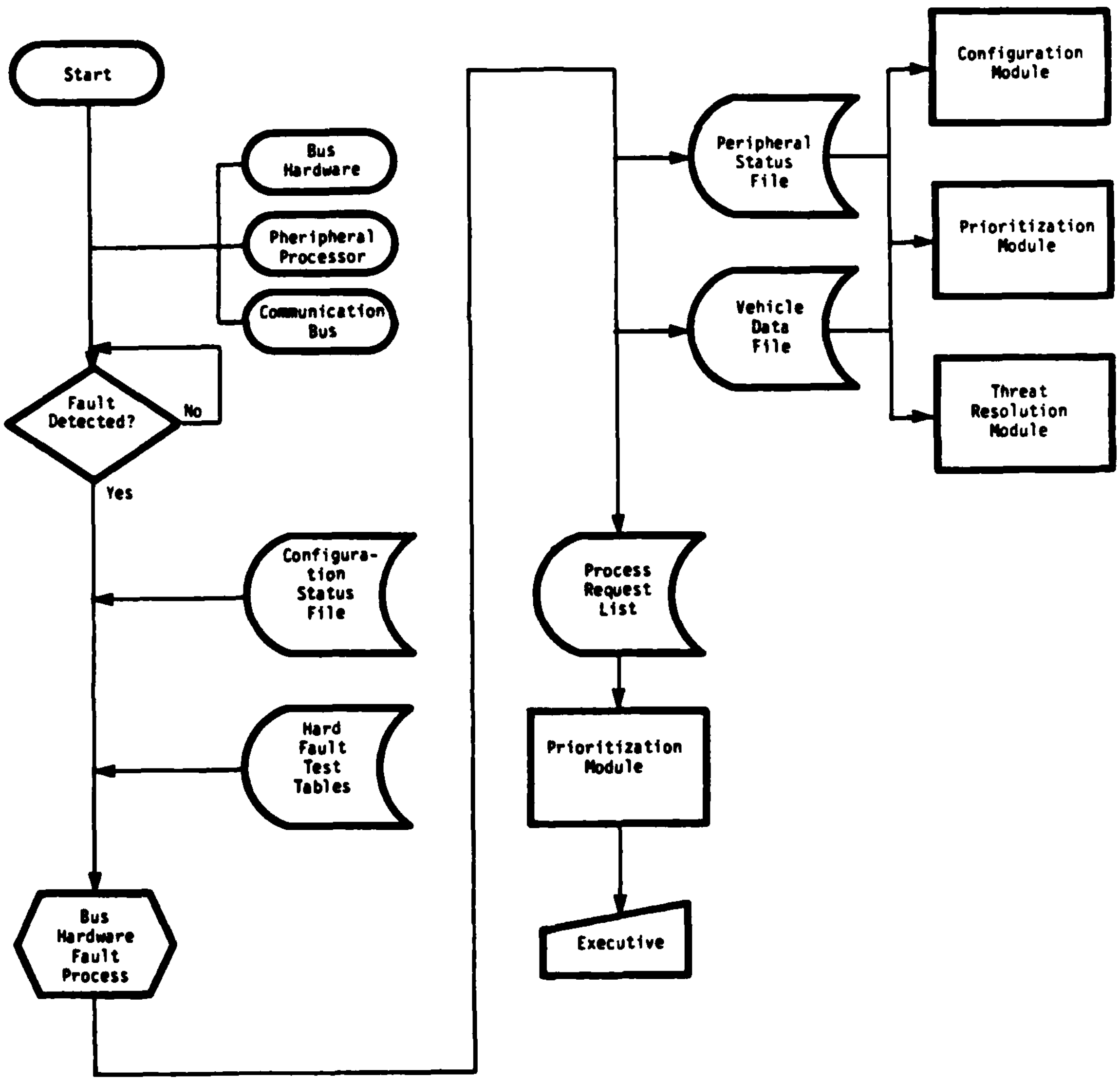

Figure 10. Schematic of System Functions Involving the Bus Hardware Fault Process in the Fault Handling Module

STATUS FAULT PROCESS

Description

The Status Fault Process, illustrated in Figure 11, performs fault handling on status errors resulting from status checks or other poll commands. The process tests the fault for recurrence and, based upon the results, performs one of three actions. Frist, if the fault is not detected, it will track the device to assure fault-free operation. Second, if the fault is detected, the device will be reset and tested again. Third, continued fault indication will cause a message to the crew telling them to remove the peripheral. The process uses the Configuration Status File and Status Fault Test Tables, updates the Peripheral Status File and the Vehicle Data File. The updated files are used by the Configuration, Prioritization and Threat Resolution Modules. The Status Fault Process also interfaces the Prioritization Module through the Process Request List. The crew message is initiated through the Control Panel Output File. The Status Fault Process works in concert with the Bus Hardware Fault Process, and the Data Content Fault Process.

Soldier-Machine Interface Implications

The only interaction between the crew and the system appears to be the message advising the crew to physically remove the failed peripheral from the system.

Recommendations

1. Sections of the Prototype Handbook relating to the interface design supporting the Status Fault Process are:

   1.1 Alphanumeric Control Methods

   2.1 Alphanumeric Displays

   2.2 Graphics Displays

   6.1 Symbols and Symbol Sets

   6.2 Standard Sets

   6.3 Abbreviations and Codes

   7.1 Error Feedback

   7.2 Error Correction and Recovery

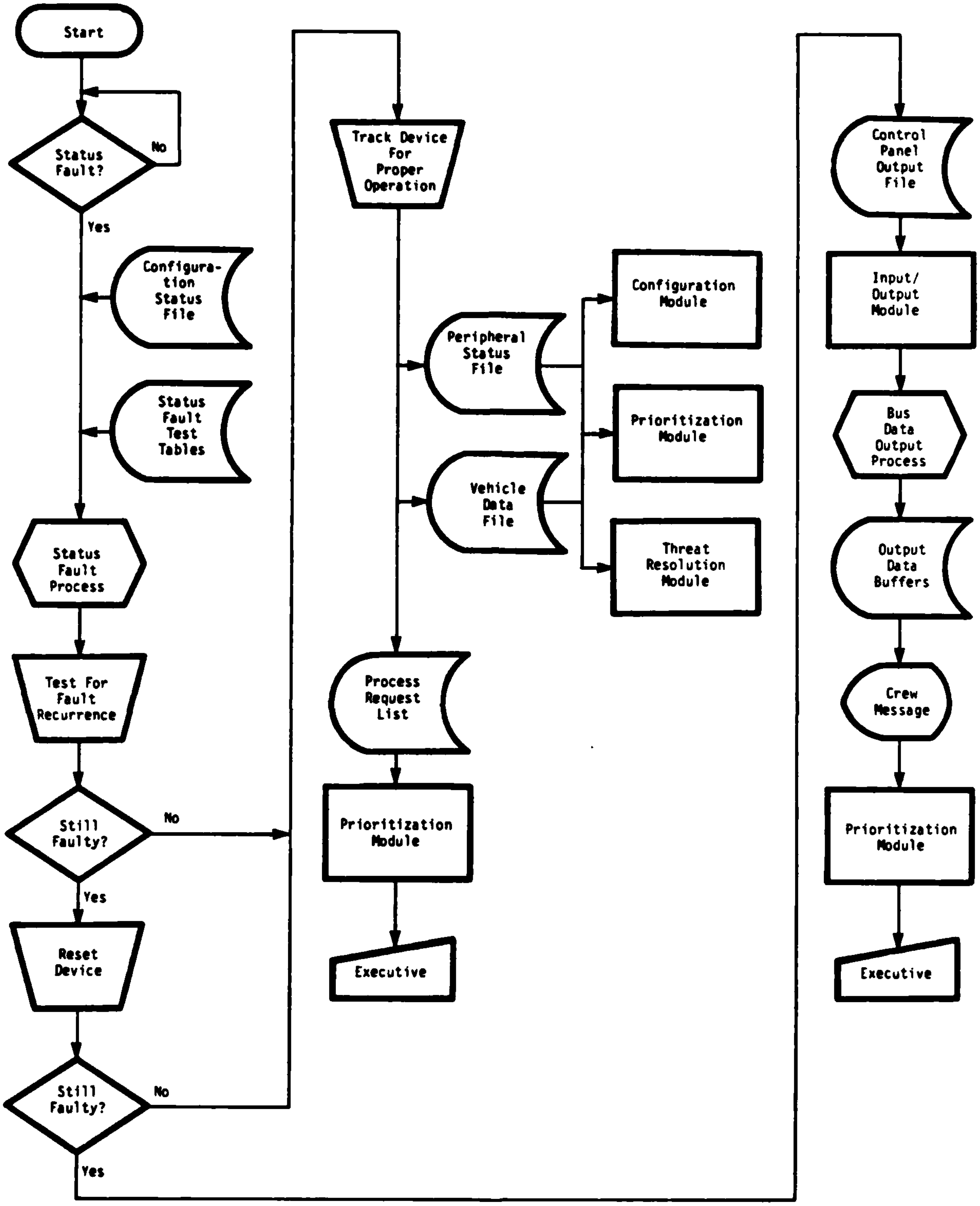

Figure 11. Schematic of System Functions Involving the Status Fault Process in the Fault Handling Module

Example of Handbook Usage. As an example, the Prototype Handbook's Section 2, Display Techniques, presents guidelines on techniques to present information to the crew.

Table 2, which is reproduced from the Prototype Handbook, illustrates applications and display techniques. The message to remove the peripheral is one type of "Fixed or Free Text Data."

Table 2. Display Techniques by Application

DISPLAY TECHNIQUE	APPLICATION: Fixed or Free Text Data	Statistical Report	Trend Data	Pictorial Symbolic Presentation	HELPs	Error Message
Alphanumeric	1	1	3	3	1	1
Graphic	3	2	1	1	2	3

KEY:

1 - APPROPRIATE

2 - ACCEPTABLE

3 - INAPPROPRIATE

To further continue the example, methods for implementing alphanumeric displays are also discussed in the Prototype Handbook. A summary of this discussion is presented as Table 3, which is reproduced from the Prototype Handbook.

Table 3. Method of Alphanumeric Display by Application

KEY:

1 - RECOMMENDED

2 - ACCEPTABLE

3 - WORKABLE BUT SUBOPTIMAL

4 - NOT RECOMMENDED OR NOT APPLICABLE

METHOD	APPLICATION: LAYOUTS FOR DATA ENTRY	DATA DISPLAY FOR IN-FORMATION OR ACTION	DISPLAY OF PERFOR-MANCE OPTIONS	PRESENTATION OF HELPs	PRESENTATION OF ERROR INFORMATION
FIXED ALPHANUMERIC DISPLAYS					
LISTS	4	1*	1*	2	3
PRESTRUCTURED FORMATS	1	1	2	2	2
HELPs	4	1	2	1	4
ERROR MESSAGES	4	2	3	4	1
VARIABLE ALPHANUMERIC DISPLAYS					
FREE TEXT REPORT	2	2	1	4	4
SHOEBOX (PERSONNEL) FILES	2	2	1	2	2

*Recommended as 1st choice for standardization purposes.

The application most appropriate to the message to remove a peripheral is the "Data Display for Information or Action." The recommended method for this application is "Lists." Thus, a one-line alphanumeric list would be the best method for presenting the message.

Recommendations 2, 3, and 4 below were derived from the Prototype Handbook.

2. Provide crew members with the capability to call a retest of the peripheral indicated.

3. Provide crew members the ability to retain a degraded peripheral in the VIDS if they feel it is providing some useful information.

4. Require crew acknowledgement of system-generated messages if those messages require crew action.

DATA CONTENT FAULT PROCESS

Description

The Data Content Fault Process, shown schematically in Figure 12, responds to data content faults and is requested each time such a fault occurs. This process initiates the Status Check or Self-Test Process which, depending on test results, may initiate the Status Fault Process. The results of the combined processes can be any one of three situations. First, the error can be corrected. Secondly, the suspect device can be reset and retested, or thirdly, a message can be generated to the crew to remove the failed peripheral.

The Data Content Fault Process updates the Peripheral Status File for use by the Configuration, Prioritization and Threat Resolution Modules. The Prioritization Module is also directly interfaced through the Process Request List. The Data Content Fault Process is supported by the Configuration Status File and the Data Content Test Tables. The process works in concert with the Bus Hardware Fault Process, the Status Fault Process, the Self-Test Process, and the Status Check Process.

Soldier Machine Interface Implications

This process requires essentially the same crew actions and reactions as the Status Fault Process and is not, therefore, discussed further here.

Recommendations

See those provided for in the Status Fault Process.

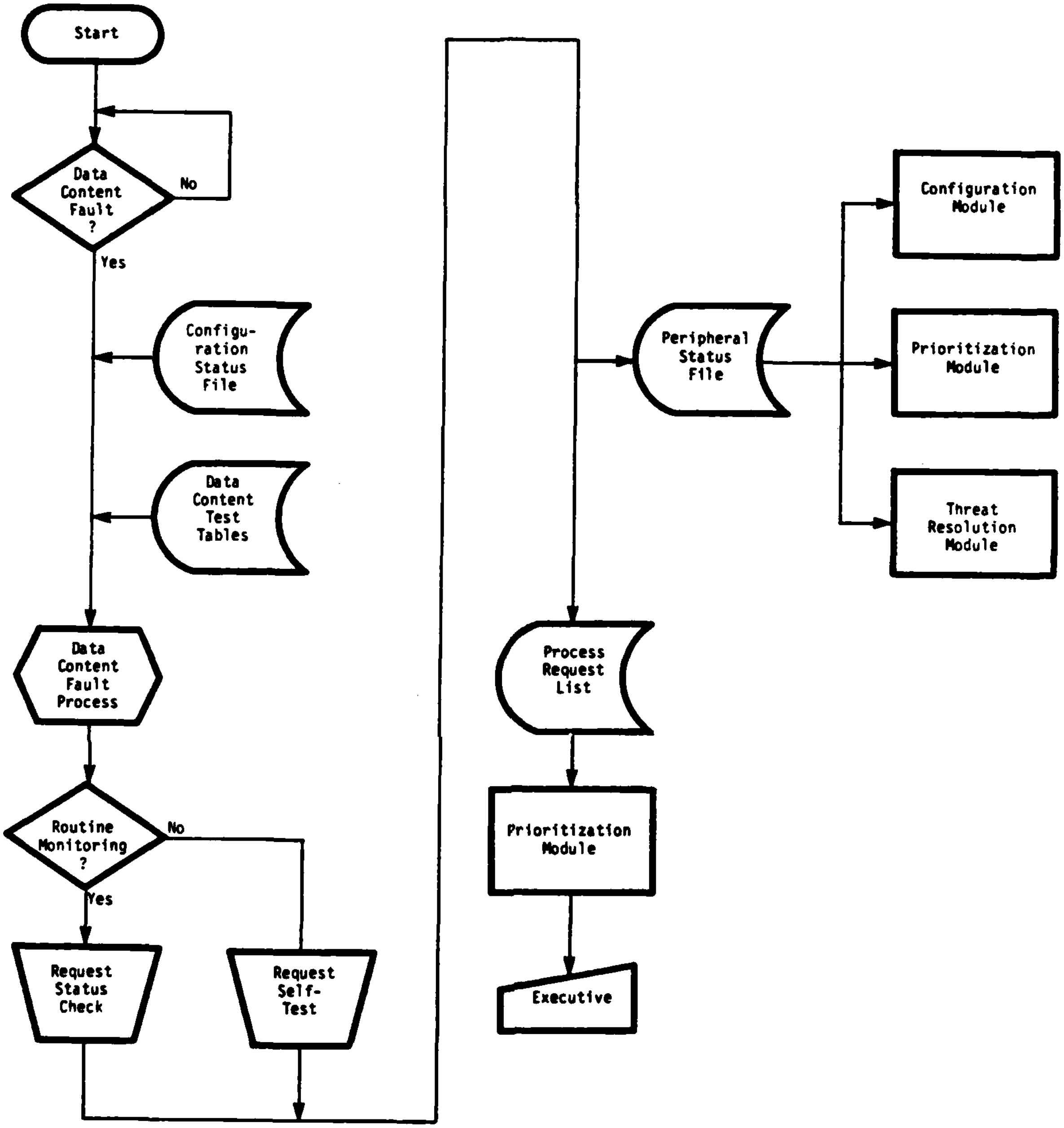

Figure 12. Schematic of System Functions Involving the Data Content Fault Process in the Fault Handling Module

Input/Output Module

The Input/Output Module carries out the transfer of data to and from peripherals as well as the preliminary sorting of data into data and status information. The Input/Output Module consists of the Interrupt Handler Process, the Bus Data Input Process, the Bus Data Output Process, and the Link Monitor Process. (NOTE: This discussion does not treat the Link Monitor Process since its function, that of providing the interface between the running operational system in the vehicle and the external development operating system, is actually external to the operatinq system with which this analysis deals.)

INTERRUPT HANDLER PROCESS

Description

The Interrupt Handler Process, illustrated in Figure 13, acknowledges, interrupts, analyzes the cause, and determines the action to be taken to resolve the interrupt. The process responds to a hardware-generated interrupt and provides interrupt-specific routines to resolve the interrupts. The Hardware Interrupt System supports the Interrupt Handler Process and calls the process when a device signals an interrupt to the CPU or operating system. The Interrupt Handler Process outputs the Process Request List which interfaces the Prioritization Module. The Interrupt Handler Process works in conjunction with the Bus Data Input, and Bus Data Output Processes of the Input/Output Module.

Soldier-Machine Interface Implications

The Interrupt Handler is, in itself, transparent to the crew. Any eventual crew action is covered through the Fault Handling Module.

Recommendations

No guidelines for interface design are applicable to this process.

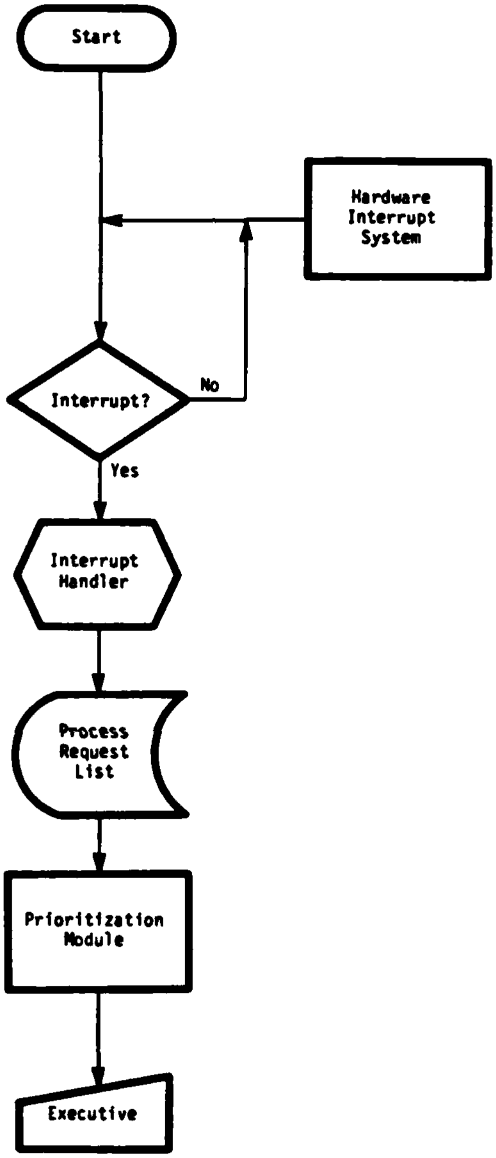

Figure 13. Schematic of System Functions Involving the Interrupt Handler Process in the Input/Output Module

BUS DATA INPUT PROCESS

Description

The Bus Data Input Process, shown schematically in Figure 14, receives peripheral information from the 1553B Bus and conditions the data for use by the operating system and application programs. This process is supported by the processes and status data received from the Input and Output Data Buffers. The Bus Data Input Process updates the Data Input Files, Status Input Files, and Process Request List. Directly interfacing the Bus Data Input Process is the Prioritization Module. The Bus Data Input Process works in conjunction with the Bus Data Output Process and Interrupt Handler of the Input/Output Module.

Soldier-Machine Interface Implications

The Bus Data Input Process does not of itself affect the Soldier-Machine Interface.

Recommendations

No guidelines for interface designs are applicable to this process.

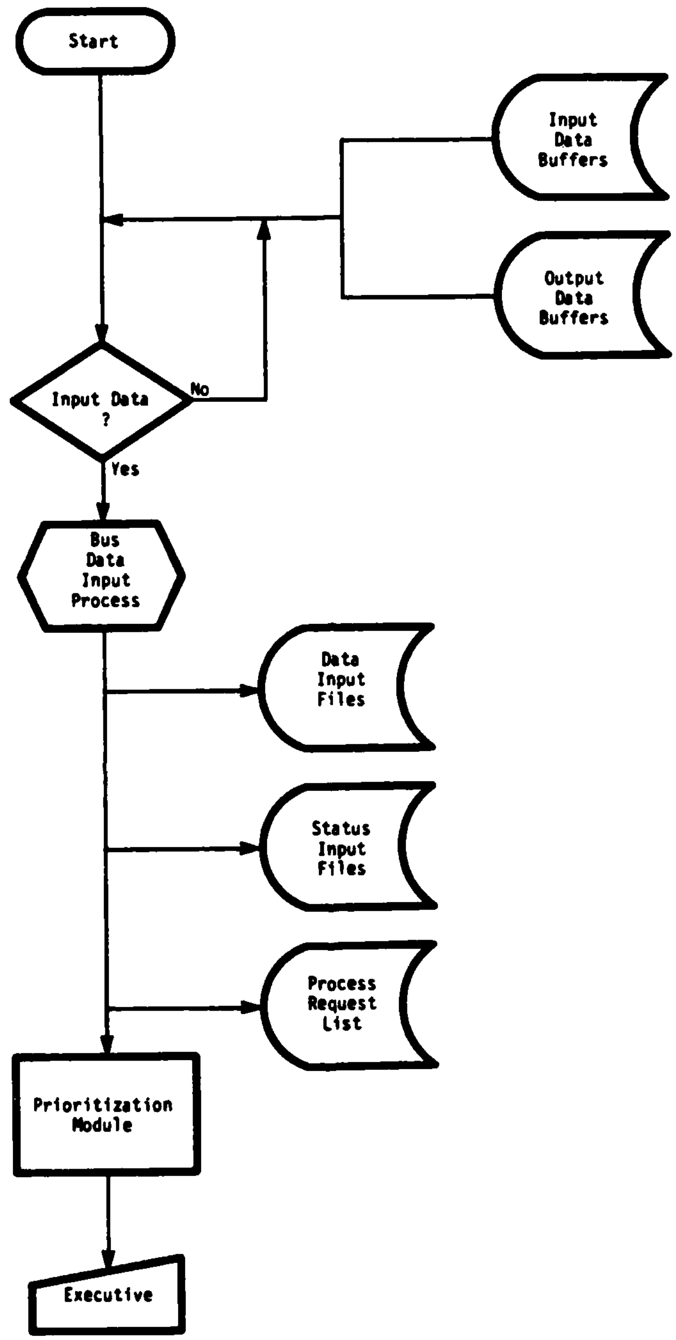

Figure 14. Schematic of System Functions Involving the Bus Data Input Process in the Input/Output Module

BUS DATA OUTPUT PROCESS

Description

The Bus Data Output Process, illustrated in Figure 15, receives data from application programs and performs the processing necessary for the system to send data to the peripherals through the 1553B Bus. The Bus Data Output Process is supported by the Control Panel Output File, the Countermeasure Activity Files, the Peripheral Command File, and the Tactical Warning Display File. The Bus Data Output Process updates the Input Data Buffers, Output Data Buffers, and the Process Request List. The Bus Data Output Process interfaces with the Prioritization Module which communicates with the Executive. The Bus Data Output Process works in conjunction with the Bus Data Input Process and the Interrupt Handler of the Input/Output Module.

Soldier-Machine Interface Implications

The Bus Data Output Process does not of itself affect the soldier-machine interface.

Recommendations

No guidelines for interface design are applicable to this process.

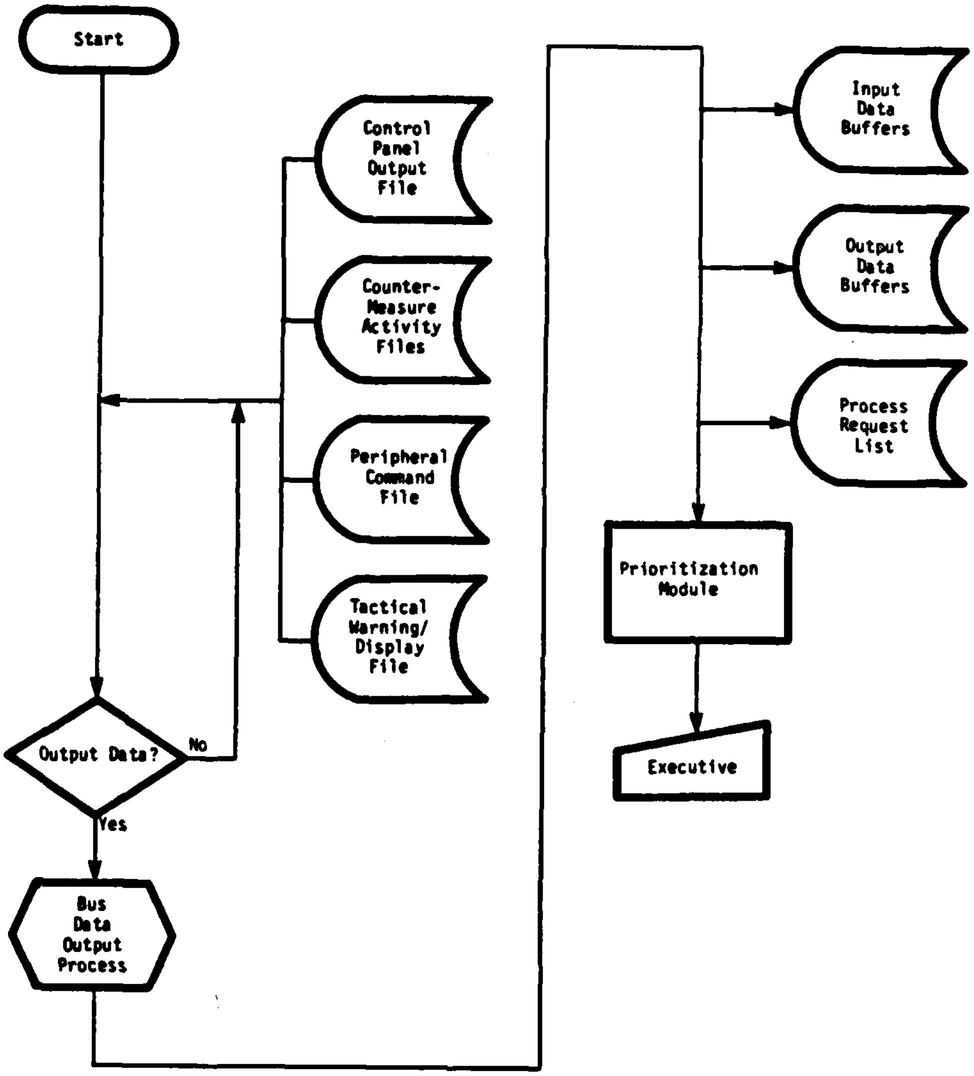

Figure 15. Schematic of System Functions Involving the Bus Data Output Process in the Input/Output Module

CONTROL PANEL MODULE

The Control Panel Module provides the software for processing data which are input to the system by vehicle crew members; it is responsible for interpreting and carrying out crew commands. The Control Panel Module consists of two processes, the Control Panel Input Process and the Command Resolution Process.

CONTROL PANEL INPUT PROCESS

Description

The Control Panel Input Process, shown schematically in Figure 16, receives commands from the crew via the Control Panel and schedules the processes necessary to carry out those commands; it converts raw commands into system commands. When a crew command is entered, the Control Panel Input Process is invoked by the Input/Output Module through the Data Input Buffers. Through the Crew Command File, the Control Panel Input Process outputs system commands to the Process Request List for use by the Prioritization Module and Process Scheduling. The Control Panel Input Process requests that when the Prioritization Module addresses the commands--via the Crew Command File--that commands not requiring a reaction be handled directly through the Command Resolution Process and that commands that do require a reaction first be handled through the Reaction Decision Process and then by the Reaction Management Module.

Soldier-Machine Interface Implications

The Control Panel Input Module handles only crew responses and commands to the system; it does not appear to have any role in system outputs to the crew. Moreover, for reasons outlined earlier under "General Findings," crew inputs typically will be terse, often consisting of a single character or symbol.

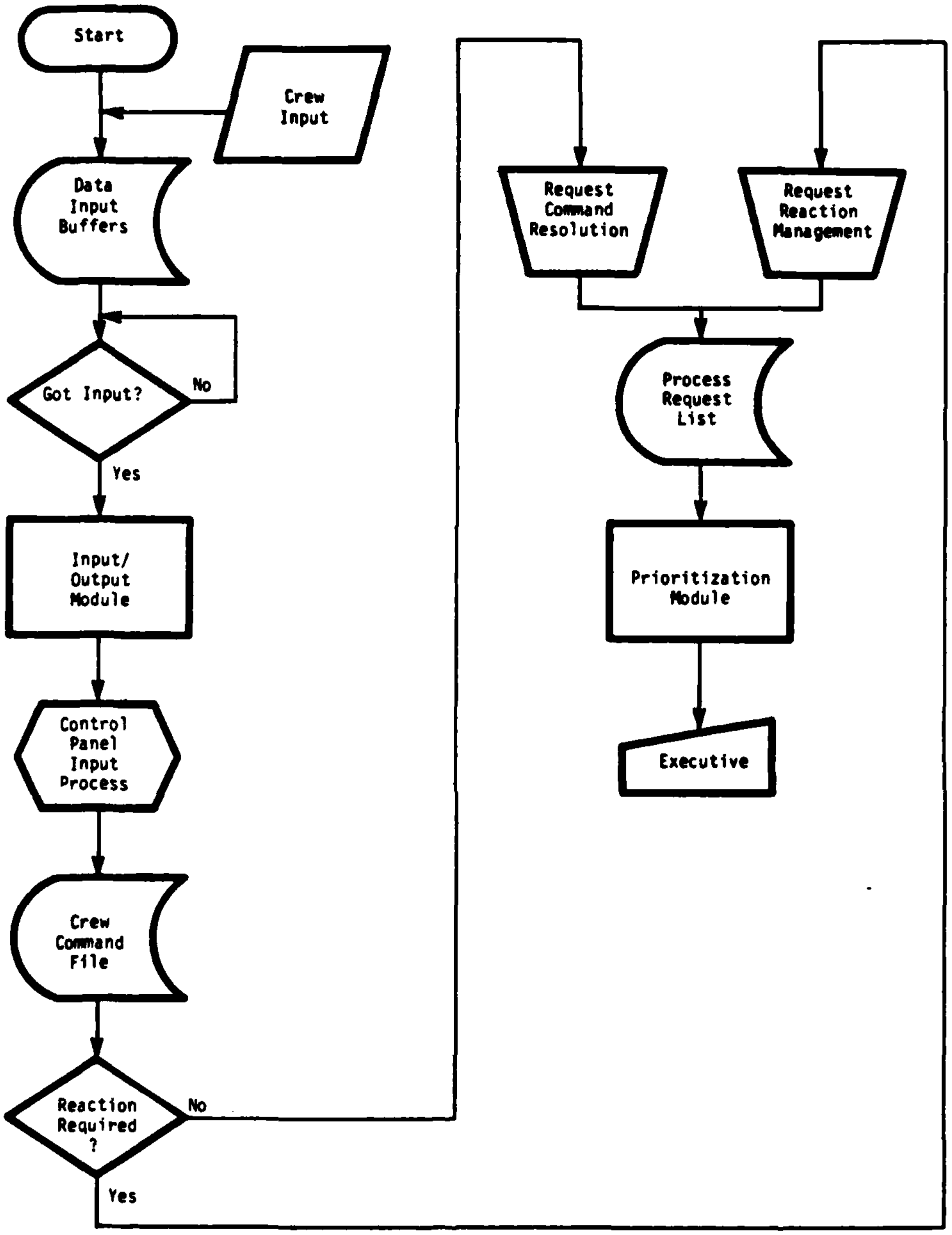

Figure 16. Schematic of System Functions Involving the Control Panel Input Process in the Control Panel Module

Recommendations

1. There appears to be no requirement for the type of alphanumeric keyboard found on typewriters (the so-called "QWERTY" keyboard). Use function keys for standard crew inputs, such as acknowledging system outputs; these might be incorporated into a touch-sensitive panel. The display device itself should have a touch-sensitive surface to permit the crew to select options merely by touching them. A high level of error detection, feedback, and correction capability will be required to permit rapid error diagnosis and correction. Guidelines appropriate to these issues will be found in sections:

   1.1 Alphanumeric Control Methods

   1.2 Graphics Control Methods

   1.3 HELPs

   3.1 Information on Legal Entries

   3.3 Interrupts and Work Recovery

   5.1 Query Methods

   7.1 Error Feedback

   7.2 Error Correction and Recovery

COMMAND RESOLUTION PROCESS

Description

The Command Resolution Process, shown schematically in Figure 17, processes all crew commands with the exception of countermeasure initiator commands. This process is requested by the Control Panel Input Process with the Crew Command File as its interface. It uses data in the Crew Command File and the Crew Command Table; it distinguishes status inputs from data requested data on the Control Panel. To achieve this, the Bus Data Output Process of the Input/Output Module is invoked via the Control Panel Output File and the message is displayed to the crew via the Output Data Buffers. For command inputs, the Command Resolution Process schedules the command using data from the Process Request List and the Configuration Status File.

Soldier-Machine Interface Implications

The Command Resolution Process does not receive crew inputs directly, and thus is not involved in the input process. It does, however, generate outputs to the crew, providing status information on demand. The need for easily understood information is thus as great here as in other modules and processes.

Recommendations

1. In designing status displays to be provided in response to crew demands, ensure that such displays respond to the specific demand. Do not, for example, generate a single, all-purpose message showing the status of all peripherals. Such a message might be appropriate for the Initial Configuration Process, but not here. If the crew wishes to see the status of the optical sensor, for example, presenting a general status message would force them to waste time scanning through the message to locate the optical sensor. Guidelines relating to status messages are contained in the following sections of the Prototype Handbook:

   2.1 Alphanumeric Displays

   2.3 Selective Highlighting

   6.1 Symbols and Symbol Sets

   6.2 Standard Terms

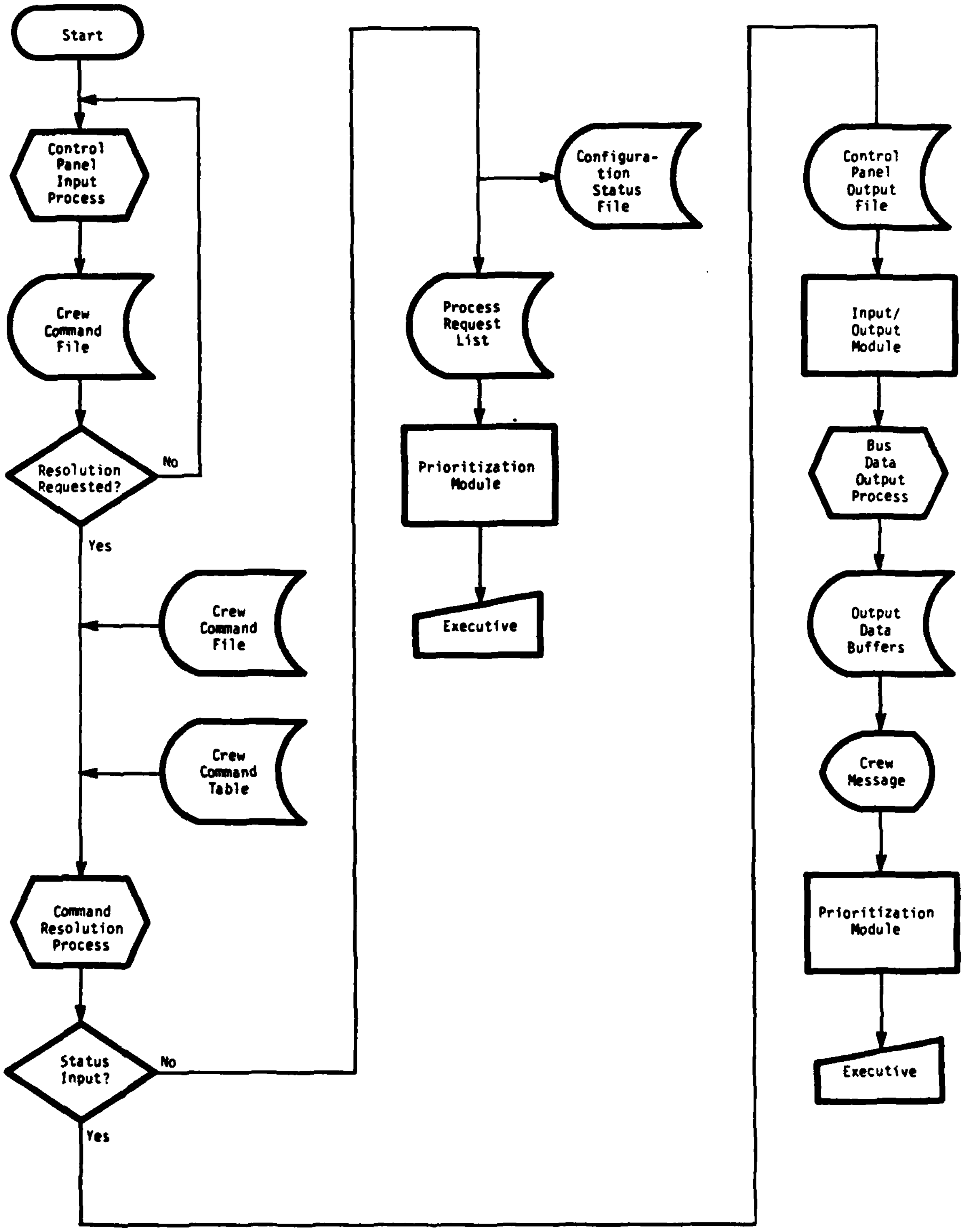

Figure 17. Schematic of System Functions Involving the Command Resolution Process in the Control Panel Module

Threat Resolution Module

The Threat Resolution Module tracks all external threats and determines appropriate reactions to those threats. The module consists of five separate processes: Threat Tracking, Sensor Cross-Correlation, Age-In, Age-Out, and Reaction Decision.

THREAT TRACKING PROCESS

Description

The Threat Tracking Process, illustrated in Figure 18, provides a separate routine for each sensor. It updates previously entered threats and initiates a tracking file for each newly identified threat. It accepts sensor data from the Input/Output Module via the Data Input Buffers, and uses data from the Threat Priority and Threat Tracking Tables and from the Vehicle Data File. The Threat Tracking Process interfaces directly with the Sensor Cross-Correlation and Age-In Processes via the Threat Tracking Tables.

Soldier-Machine Interface Implications

This process does not by itself affect the soldier-machine interface.

Recommendations

As the Threat Tracking Process does not affect the operation of the interface, no guidelines are required.

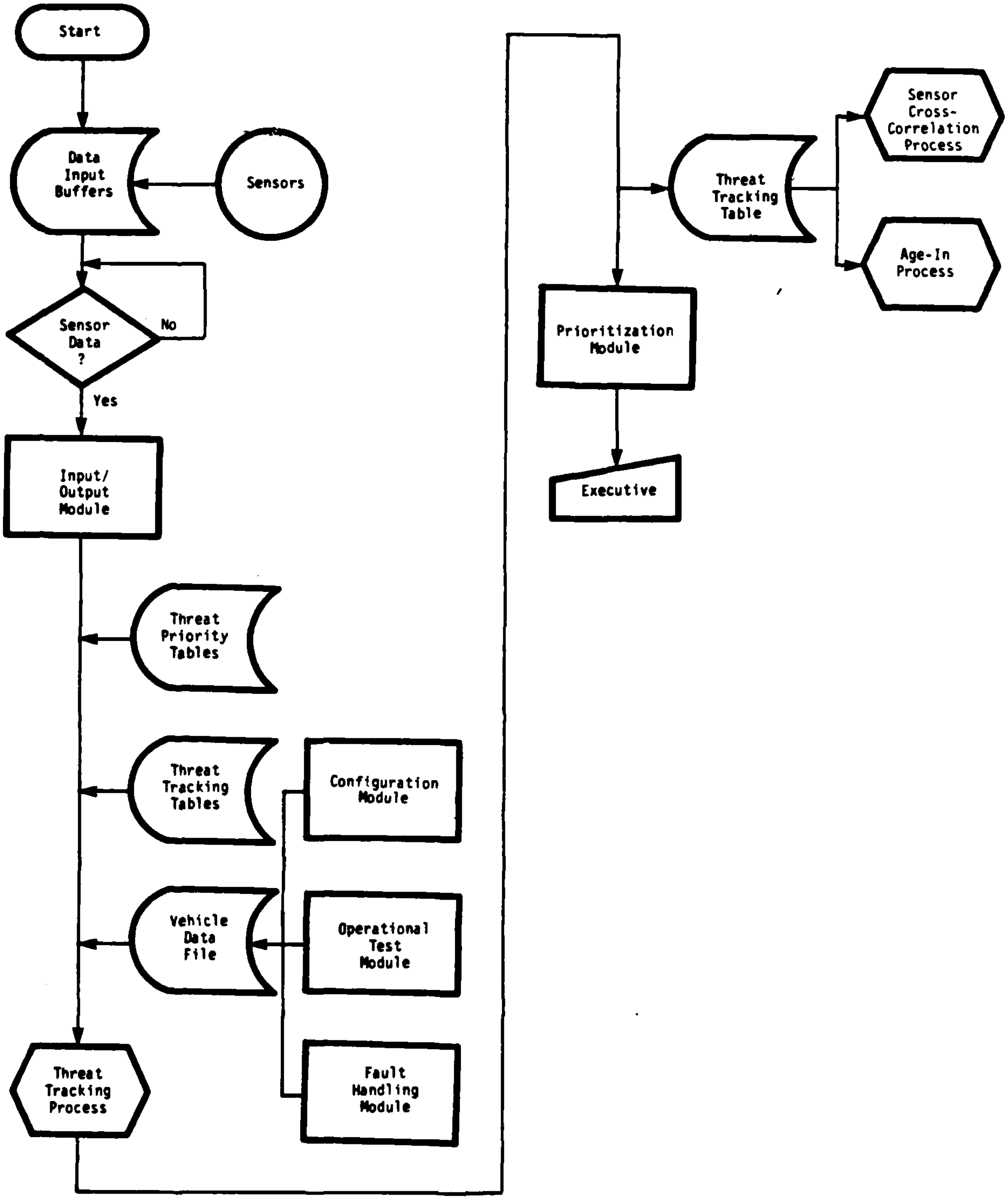

Figure 18. Schematic of System Functions Involving the Threat Tracking Process in the Threat Resolution Module

SENSOR CROSS-CORRELATION PROCESS

Description

The Sensor Cross-Correlation Process, shown schematically in Figure 19, provides multiple routines that correlate threat data detected by the different sensors to construct multisensory data monitored in the Threat Correlation Files. The Sensor Cross-Correlation Process is requested by the Threat Tracking Process. Its purpose is to determine whether sensor cross-correlation of new data received from a particular sensor is appropriate, and if so, to update previously entered data or to enter new data in the Threat Correlation Files. The Sensor Cross-Correlation Process uses the data in the Sensor Cross-Correlation Tables, the Threat Priority Tables, and the Vehicle Data File which are updated by the Configuration Module, the Operational Test Module, and the Fault Handling Module. The Sensor Cross-Correlation Tables are threat object templates containing threat identification signal types, probabilities, and confidence levels which merge Threat Tracking Files into multisensory signal input correlation files. The Sensor Cross-Correlation Process also outputs results to the Prioritization Module for Process Scheduling.

Soldier-Machine Interface Implications

The data gathered, processed, and output by the Sensor Cross-Correlation Process do not impact the soldier-machine interface as part of the Sensor Cross-Correlation process. This process updates the Threat Correlation Files with data that ultimately results in a crew message. However, this message will be handled through the Reaction Management Module.

Recommendations

As the Sensor Cross-Correlation Process does not directly impact the SMI, no interface guidelines are applicable.

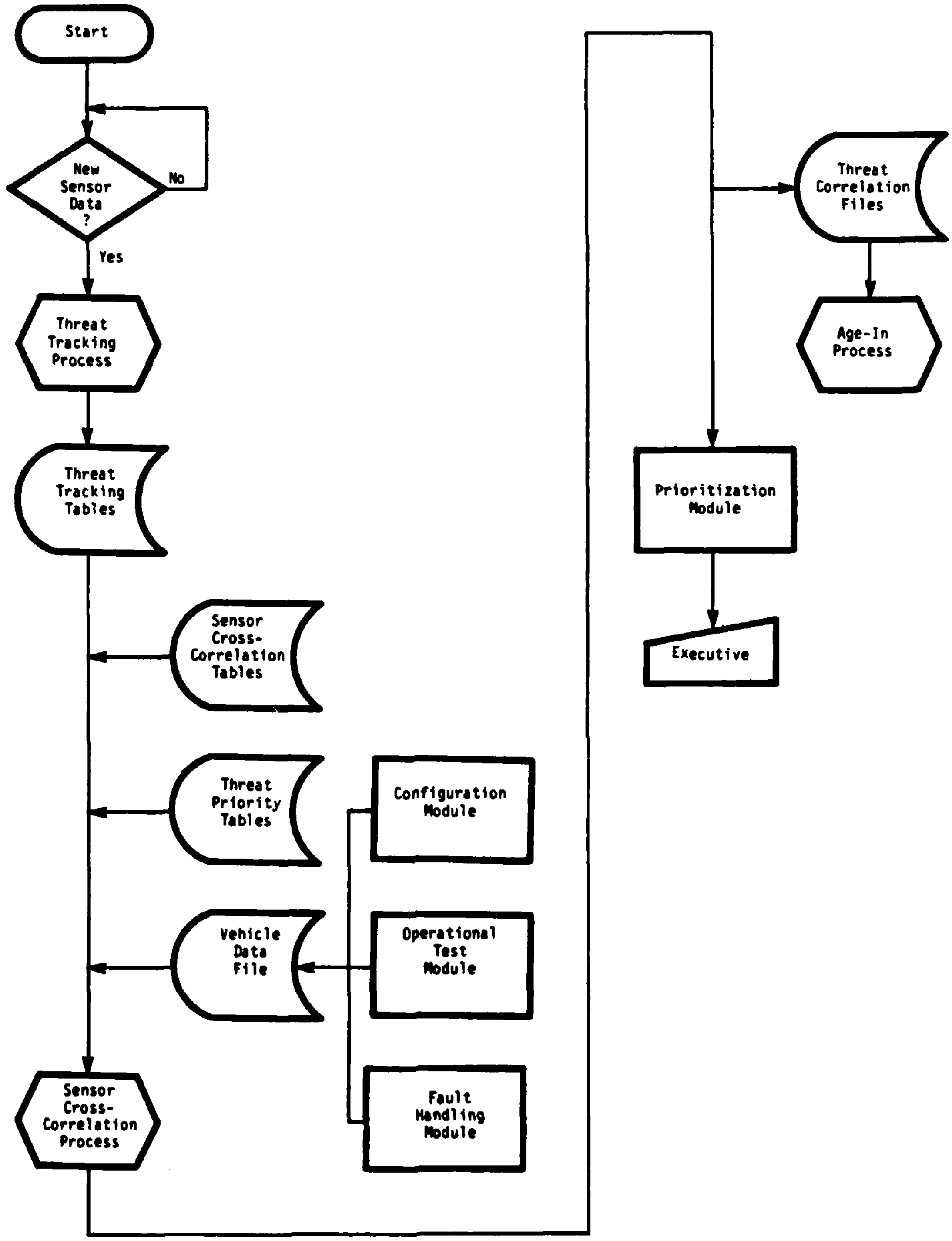

Figure 19. Schematic of System Functions Involving the Sensor Cross-Correlation Process in the Threat Resolution Module

AGE-IN PROCESS

Description

The Age-In Process, shown schematically in Figure 20, evaluates the duration and consistency of tracked threats for inclusion in (or exclusion from) the Prioritized Threat List. By request of the Threat Tracking Process and the Sensor Cross-Correlation Process, it functions to determine whether their output into the Threat Tracking Tables or the Threat Correlation Tables should be used to create new entries or to update existing entries in the Prioritized Threat List by comparison of these data against those of the Aging Tables. The Aging Tables contain duration, frequency, and consistency parameters for each threat type which may appear in the Threat Track and Threat Correlation Files. The Age-In Process also interfaces directly with the Reaction Decision Process via the Prioritized Threat List and with Process Scheduling via the Prioritization Module.

Soldier-Machine Interface Implications

The Age-In Process does not directly affect the SMI. The data it produces can conceivably be used by additional processes that will require an SMI. However, the Age-In Process does not require an SMI to accomplish its processing.

Recommendations

As the Age-In Process does not impact the SMI, no interface guidelines are applicable.

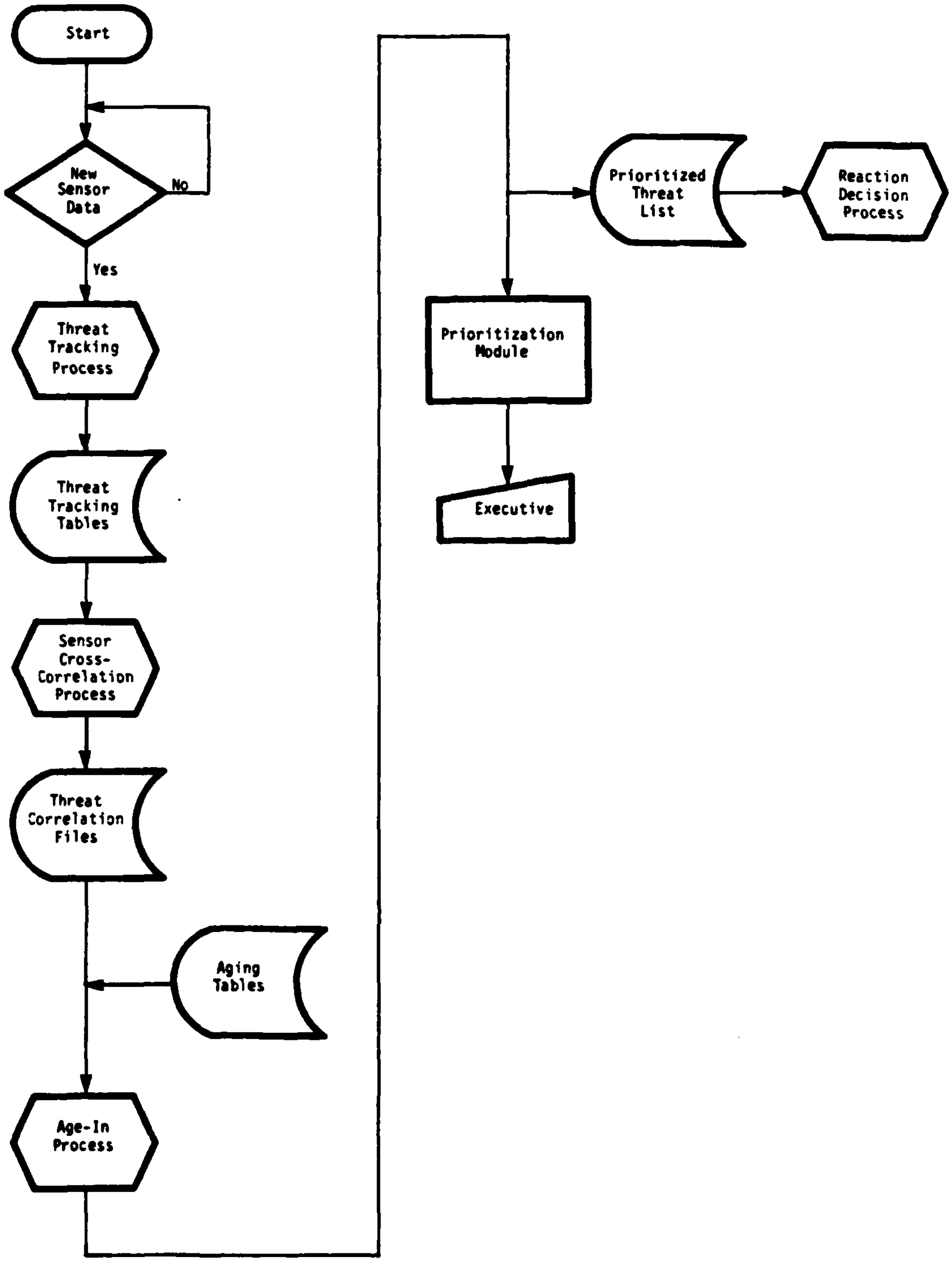

Figure 20. Schematic of System Functions Involving the Age-In Process in the Threat Resolution Module

AGE-OUT PROCESS

Description

The Age-Out Process, illustrated in Figure 21, determines whether the records pertaining to tracked threats should be deleted due to a lack of update data from the relevant sensors. The Age-Out Process is requested by the Prioritized Threat List and uses the Aging Tables. It affects all other Threat Resolution processes via the Prioritized Threat List, the Threat Correlation Files, and the Threat Tracking Files.

Soldier-Machine Interface Implications

The Age-Out Process does not interact with the SMI. The data it produces can conceivably be used by additional processes that will require a SMI. However, the Age-Out Process does not require an SMI to accomplish its processing.

Recommendations

As the Age-Out Process does not impact the SMI, no interface guidelines are applicable.

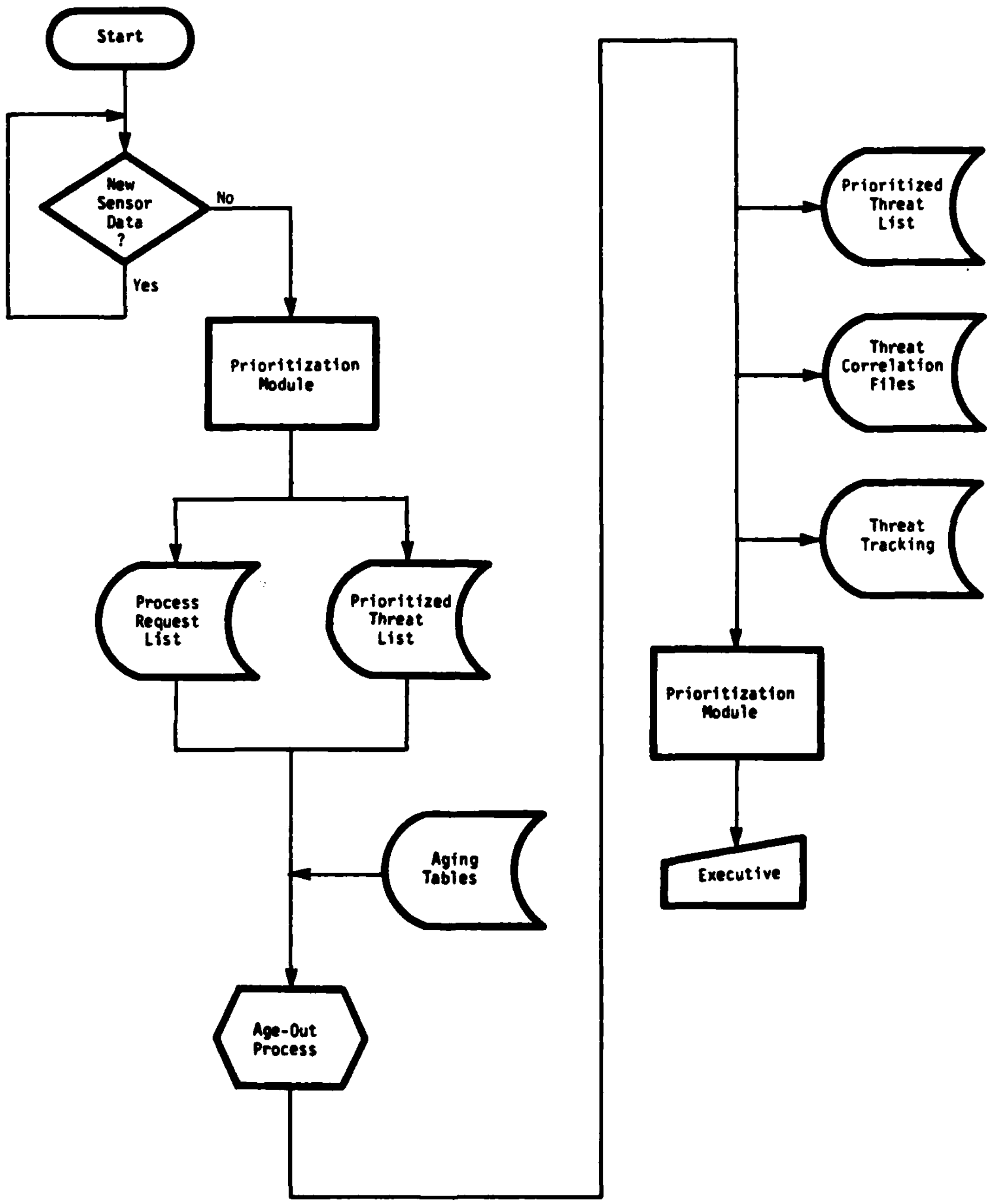

Figure 21. Schematic of System Functions Involving the Age-Out Process in the Threat Resolution Module

REACTION DECISION PROCESS

Description

The Reaction Decision Process, shown schematically in Figure 22, is requested by the Age-In Process when new threat data are available from the sensors. Its function is to issue an appropriate reaction request which accommodates potential conflicts with ongoing reactions and to the availability of reaction resources in response to new threat data. It uses data from the Prioritized Threat List and also the Peripheral Status File, the Reaction Decision Tables, and the Vehicle Data Files. The Peripheral Status File maintains data on the presence and operational status of all peripheral components, including sensors, countermeasure devices, crew interaction devices, and the communication bus. The Reaction Decision Tables contain lists of prioritized reactions and priority modification values for each possible threat and tactical environment condition. The Reaction Decision Process interfaces directly with the Reaction Management Module via the Reaction Data File.

Soldier-Machine Interface Implications

The Reaction Decision Process calls the Reaction Management Module in the event threat data warrents a reaction from the crew. Any interface implication is generated through that module.

Recommendations

As the Reaction Decision Process does not impact the SMI, no interface guidelines are applicable.

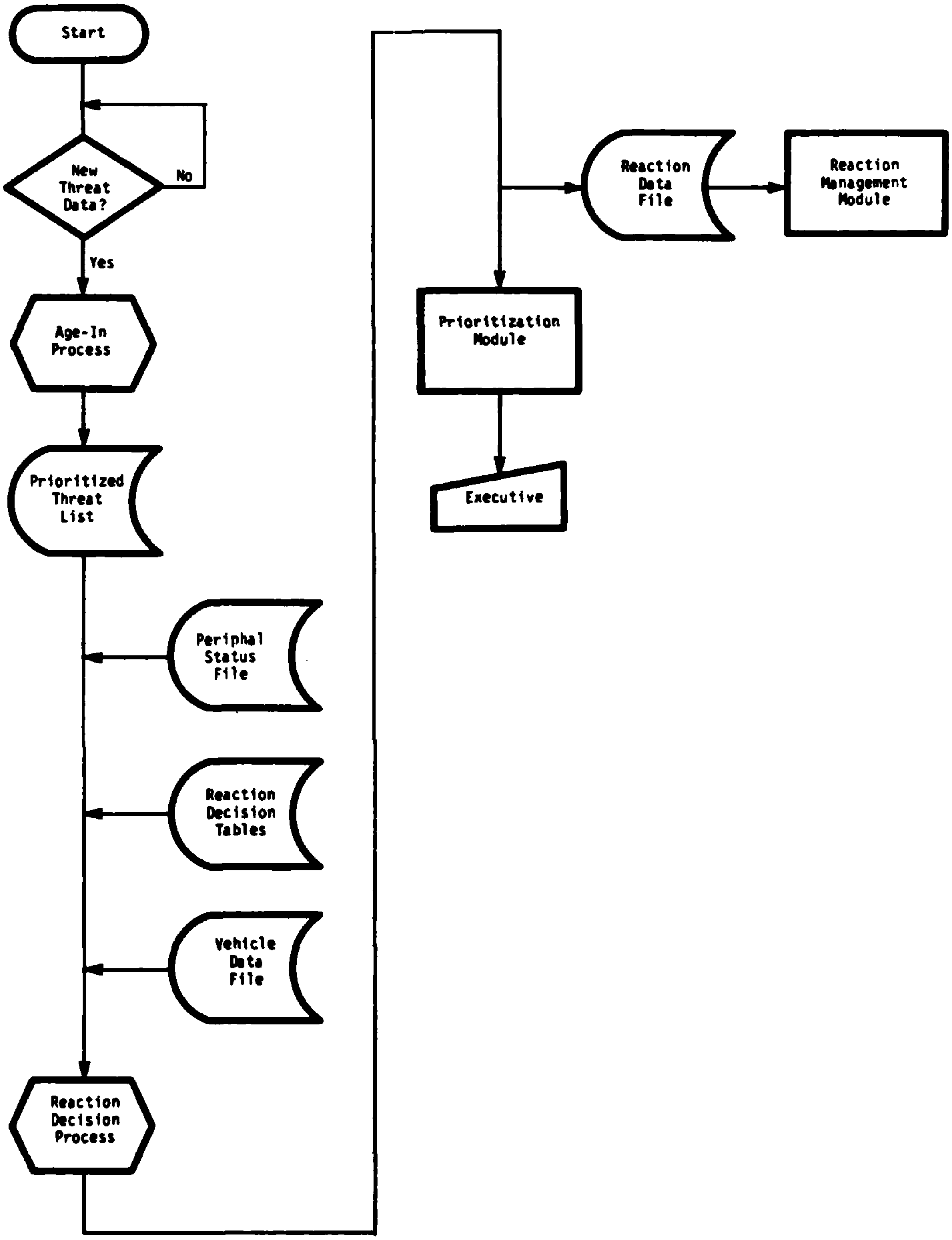

Figure 22. Schematic of System Functions Involving the Reaction Decision Process in the Threat Resolution Module

Reaction Management Module

Description

The Reaction Management Module shown schematically in Figure 23 initiates, maintains, and suspends countermeasure actions and generates information and warnings which are displayed to the crew. Its purpose is to resolve conflicts between reaction preferences presented by the Reaction Data File via the Reaction Decision Process and those indicated by the crew via the Control Panel and the Control Panel Output File and then to issue commands to peripheral countermeasure devices and to crew displays accordingly.

The Reaction Management Module is requested by and interacts directly with the Age-In Process using the Prioritized Threat List. It uses data in the Peripheral Status File and the Vehicle Data File which are updated by the Configuration Module, the Operational Test Module, and the Fault Handling Module. It also uses data from the Reaction Data File which is input through the Reaction Decision Process and from the Control Panel Output File which is input by the crew via the Control Panel. Output of the Reaction Management Module is to the Countermeasure Activity File and to the Tactical Warning Display File. The Tactical Warning Display File functions through the Bus Data Output Process of the Input/Output Module and the Output Data Buffers to announce the resolution of any conflict between the threat indications of the Reaction Data File and the Control Output Data File. When a conflict is resolved, commands are issued to peripheral countermeasure devices and warnings are issued to the crew, as appropriate.

Soldier-Machine Interface Implications

During combat operations, the Reaction Management Module probably will generate more crew-system interaction than all other modules combined--and will do so under extremely adverse conditions. Therefore, this module's interactions with the crew must be designed with the utmost care to provide rapid completion of transactions while reducing error opportunities to a minimum.

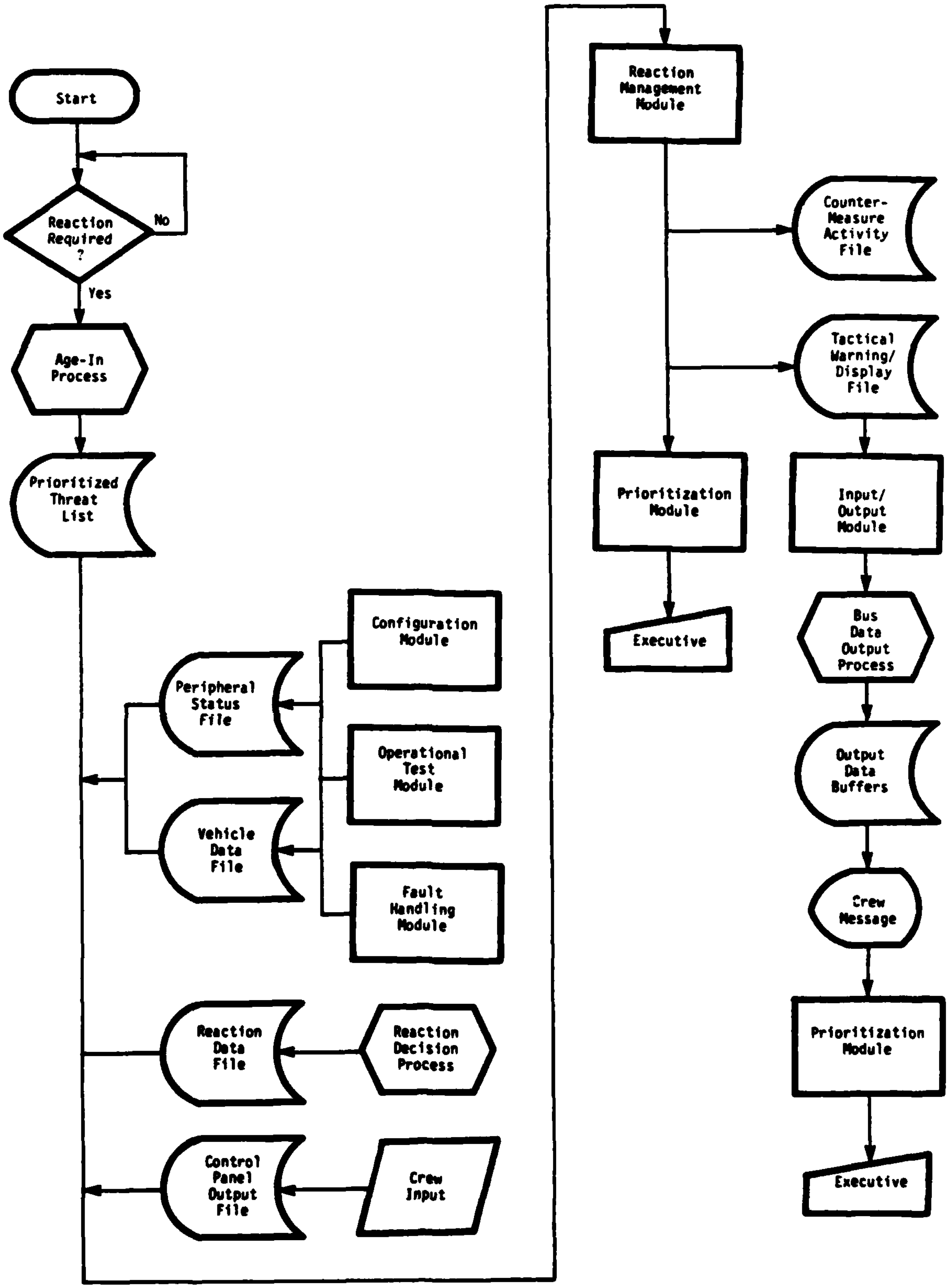

Figure 23. Schematic of System Functions of the Reaction Management Module

Recommendations

1. The Reaction Management Module should present threat warnings to the crew via graphics displays to the greatest extent feasible. Such displays should include a map overlay showing the location of the VIDS-equipped vehicle and relative positions of threats. Threats should be represented by easily recognized symbols--which may require research to identify. Guidelines concerned with graphics are presented in the following sections of the Prototype Handbook:

   2.2 Graphics Displays

   2.3 Selective Highlighting

2. Audio displays should be used for alerts rather than for information presentation. That is, when a threat warning is displayed, an audible alarm presented via the intercom can be used to draw the crew's attention to the display. While this alarm could be a simple noise such as a buzz or bell, a spoken message (e.g., "ENEMY TANK ON THE SCREEN") would be more effective. However, because the vehicle intercom is used for other purposes, audio messages should be kept short.

3. Crew inputs to the Reaction Management Module may be feasible through the graphics display device, for example, by using a touch-sensitive surface on the screen. Depending on further analysis of the module, however, alphanumeric input methods may also be necessary. Guidelines appropriate to input functions are contained in sections:

   1.1 Alphanumeric Control Methods

   1.2 Graphics Control Methods

   1.3 HELPs

   3.1 Information on Legal Entries

   3.2 Unburdening of Input

   3.3 Interrupts and Work Recovery

   4.1 Composition Aids for Alphanumeric Messages (for input)

   4.2 Composition Aids for Graphics Displays (for input)

   6.1 Symbols and Symbol Sets

   6.2 Standard Terms

SUMMARY

As noted above under "General Findings," soldier-machine interaction with the VIDS-DMS will differ considerably from that with many other battlefield automated systems. First, the volume of transactions will be lower, in that the system will present information and ask for crew responses primarily on an exception basis. The crew will be busy with other tasks required to operate the vehicle, and will have little time for VIDS-related tasks despite their importance (reaction management will be the exception, of course). Second, while minimal demand on the soldier's intellectual and physical resources is typically desirable in battlefield automated systems, in the VIDS-DMS it will be an urgent requirement. The purpose of the system demands that meaningful, understandable information be presented and correct crew responses be obtained quickly. Delays caused by the need to ponder an ambiguous output or to deliberate over input decisions could lead to the literal destruction of the vehicle and its crew.

For all these reasons, the design of the VIDS-DMS will be critical to optimum operation of the system and to successful performance of its mission. System messages to the crew must be brief, fully informative, and free of redundancy and extraneous detail. Input requirements must be clear to the crew, and input methods must permit expeditious command and data entry. To meet these requirements, Synectics has recommended the transactional features described in the preceding section and suggested sections of the Prototype Handbook that provide guidance appropriate to these features. Table 4 summarizes these guideline sections by module and process.

Table 4. Summary of Recommended Guidelines for SMI of VIDS-DMS Modules and Processes

MODULE/PROCESS	1. CONTROL METHODS	1.1 Alphanumeric Control Methods	1.2 Graphics Control Methods	1.3 HELPs	2. DISPLAY TECHNIQUES	2.1 Alphanumeric Displays	2.2 Graphics Displays	2.3 Selective Highlighting	3. DATA ENTRY AND HANDLING	3.1 Information on Legal Entries	3.2 Unburdening of Input	3.3 Interrupts and Work Recovery	4. MESSAGE COMPOSITION AIDS	4.1 Composition Aids for Alphanumeric Messages	4.2 Composition Aids for Graphics Displays	5. DATA RETRIEVAL ASSISTANCE	5.1 Query Method	5.2 Query Structure	6. SYMBOLOGY AND TERMINOLOGY	6.1 Symbol and Symbol Sets	6.2 Standard Terms	6.3 Abbreviations and Codes	6.4 Full Language	6.5 Glossaries	7. ERROR HANDLING	7.1 Error Feedback	7.2 Error Correction and Recovery
POWER UP MODULE		X				X		X													X						
PRIORITIZATION MODULE																											
CONFIGURATION MODULE																											
Initial Configuration		X				X		X													X						
Failure Reconfiguration		X				X		X		X	X									X	X	X				X	X
Fault Reconfiguration		X				X		X		X	X									X	X	X				X	X
Tactical Reconfiguration		X				X	X			X	X									X	X	X				X	X
OPERATIONAL TEST MODULE																											
Status Check																											
Self-Test		X		X		X		X		X	X									X	X					X	X
FAULT HANDLING MODULE																											
Bus Hardware Fault																											
Status Fault		X				X	X													X	X	X				X	X
Data Content Fault		X				X	X													X	X	X				X	X
INPUT/OUTPUT FAULT																											
Interrupt Handler																											
Bus Data Input																											
Bus Data Output																											
CONTROL PANEL MODULE																											
Control Panel Input		X	X	X						X		X					X									X	X
Command Resolution						X	X													X	X						
THREAT RESOLUTION MODULE																											
Threat Tracking																											
Sensor Cross-Corp.																											
Age-In																											
Age-Out																											
Reaction Desision																											
REACTION MANAGEMENT		X	X	X			X	X		X	X	X		X	X					X	X						

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